



# **ShipMo3D Version 1.0 User Manual for Simulating Time Domain Motions of a Freely Maneuvering Ship in a Seaway**

*Kevin McTaggart*

**Defence R&D Canada – Atlantic**

Technical Memorandum  
DRDC Atlantic TM 2007-172  
October 2007

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Chair/Document Review Panel

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# Abstract

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This report serves as a user manual for simulating ship motions in waves and in calm water using ShipMo3D Version 1.0. ShipMo3D is an object-oriented library with associated user applications for predicting ship motions in both the time domain and frequency domain. This report covers simulation in the time domain, and a companion report serves as a user manual for predicting ship motions in the frequency domain. Several ShipMo3D applications are used for obtaining a simulation in the time domain. SM3DPanelHull creates a panelled representation of the ship hull using input offsets. SM3DRadDif generates a database of radiation and diffraction coefficients that contribute to the efficiency of subsequent simulations. SM3DBuildShip creates a model of the ship, including required data for the hull geometry, radiation and diffraction properties, and appendage geometries. SM3DBuildSeaway creates a model of a seaway, which can consist of either regular waves or random waves, with capabilities for modelling both unidirectional and multidirectional seaways. SM3DFreeMo simulates motions of a ship using input data prepared by the user and produced by the previously mentioned ShipMo3D applications.

# Résumé

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Le présent rapport constitue un guide de l'utilisateur pour la simulation des mouvements de navires dans les vagues et dans les eaux calmes au moyen de ShipMo3D, version 1.0. ShipMo3D est une bibliothèque orientée objet dotée d'applications utilisateur connexes permettant de prévoir les mouvements des navires dans le domaine temporel et dans le domaine fréquentiel. Le présent rapport traite de la simulation dans le domaine temporel, alors qu'un rapport complémentaire sert de guide de l'utilisateur pour la prévision des mouvements des navires dans le domaine fréquentiel. Plusieurs applications ShipMo3D contribuent à l'obtention d'une simulation dans le domaine temporel. SM3DPanelHull crée une représentation par panneaux de la coque du navire à partir de décalages d'entrée. SM3DRadDif produit une base de données contenant des coefficients de rayonnement et de diffraction, qui contribue à l'efficacité des simulations subséquentes. SM3DBuildShip crée un modèle de navire intégrant les données requises sur la géométrie de la coque, les propriétés de rayonnement et de diffraction et la géométrie des appendices. SM3DBuildSeaway établit un modèle de voie maritime, qui peut comporter des vagues régulières ou des vagues aléatoires, et il peut modéliser les voies maritimes unidirectionnelles et multidirectionnelles. SM3DFreeMo simule les mouvements d'un navire à partir des données d'entrée préparées par l'utilisateur et produites par les applications ShipMo3D mentionnées précédemment.

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# Executive summary

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## ShipMo3D Version 1.0 User Manual for Simulating Time Domain Motions of a Freely Maneuvering Ship in a Seaway

Kevin McTaggart; DRDC Atlantic TM 2007-172; Defence R&D Canada – Atlantic; October 2007.

**Introduction:** ShipMo3D is an object-oriented library with associated user applications for predicting ship motions in calm water and in waves. Motion predictions are available in both the frequency domain and the time domain. For predictions in the frequency domain, a ship is assumed to travel with quasi-steady speed and heading in waves. For predictions in the time domain, the ship can be freely maneuvering in either calm water or in waves. This report serves as a user manual for simulation of motions in the time domain. A companion report provides a user manual for motion predictions in the frequency domain.

**Principal Results:** Several ShipMo3D applications documented within are used for obtaining a simulation in the time domain. SM3DPanelHull creates a panelled representation of the ship hull using input offsets. SM3DRadDif generates a database of radiation and diffraction coefficients that contribute to the efficiency of subsequent simulations. SM3DBuildShip creates a model of the ship, including required data for the hull geometry, radiation and diffraction properties, and appendage geometries. SM3DBuildSeaway creates a model of a seaway, which can consist of either regular waves or random waves, with capabilities for modelling both unidirectional and multidirectional seaways. SM3DFreeMo simulates motions of a ship using input data prepared by the user and produced by the previously mentioned ShipMo3D applications.

**Significance of Results:** ShipMo3D can now be used to produce repeatable, non-interactive time domain simulations of ship motions in calm water and in waves. These simulations can be used for various applications, including engineering analysis, operations analysis, and training.

**Future Plans:** Additional ship motion prediction capabilities are being developed using ShipMo3D. The modelling of azimuthing propulsors, such as Z-drives, is being introduced. User applications are being developed for predicting motions of two ships in close proximity, including the modelling of hydrodynamic interactions.

# Sommaire

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## ShipMo3D Version 1.0 User Manual for Simulating Time Domain Motions of a Freely Maneuvering Ship in a Seaway

Kevin McTaggart ; DRDC Atlantic TM 2007-172 ; R & D pour la défense Canada – Atlantique ; octobre 2007.

**Introduction :** ShipMo3D est une bibliothèque orientée objet dotée d'applications utilisateur connexes permettant de prévoir les mouvements des navires dans les eaux calmes et dans les vagues. Des prévisions de mouvement sont possibles dans le domaine fréquentiel et dans le domaine temporel. Pour les prévisions dans le domaine fréquentiel, un navire est supposé se déplacer à une vitesse et à un cap essentiellement stables dans les vagues. Pour les prévisions dans le domaine temporel, le navire peut librement manœuvrer dans les eaux calmes ou dans les vagues. Le présent rapport constitue un guide de l'utilisateur pour la simulation des mouvements dans le domaine temporel. Un rapport complémentaire sert de guide de l'utilisateur pour la prévision des mouvements dans le domaine fréquentiel.

**Résultats principaux :** Plusieurs applications ShipMo3D décrites dans le présent document contribuent à l'obtention d'une simulation dans le domaine temporel. SM3D-PanelHull crée une représentation par panneaux de la coque du navire à partir de décalages d'entrée. SM3DRadDif produit une base de données contenant des coefficients de rayonnement et de diffraction, qui contribue à l'efficacité des simulations subséquentes. SM3DBuildShip crée un modèle de navire intégrant les données requises sur la géométrie de la coque, les propriétés de rayonnement et de diffraction et la géométrie des appendices. SM3DBuildSeaway établit un modèle de voie maritime, qui peut comporter des vagues régulières ou des vagues aléatoires, et il est capable de modéliser les voies maritimes unidirectionnelles et multidirectionnelles. SM3DFreeMo simule les mouvements d'un navire à partir des données d'entrée préparées par l'utilisateur et produites par les applications ShipMo3D mentionnées précédemment.

**Importance des résultats :** ShipMo3D peut maintenant produire, dans le domaine temporel, des simulations non interactives répétables des mouvements des navires dans les eaux calmes et dans les vagues. Ces simulations peuvent servir à diverses applications, notamment aux analyses techniques, aux analyses d'opérations et à l'ins-truction.



**Travaux ultérieurs prévus :** On met actuellement au point des ressources supplémentaires de prévision des mouvements des navires au moyen de ShipMo3D. La modélisation des propulseurs orientables en azimuth, par exemple à transmission en Z, fait son apparition. Des applications utilisateur sont mises au point pour la prévision des mouvements de deux navires rapprochés, y compris la modélisation des interactions hydrodynamiques.

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# Table of contents

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Abstract . . . . .	i
Résumé . . . . .	i
Executive summary . . . . .	iii
Sommaire . . . . .	iv
Table of contents . . . . .	vii
List of tables . . . . .	x
List of figures . . . . .	x
1 Introduction . . . . .	1
2 Overview of Using ShipMo3D for Predicting Motions for a Freely Maneuvering Ship . . . . .	1
3 Coordinate Systems . . . . .	5
4 Panelling of the Ship Hull - SM3DPanelHull . . . . .	8
4.1 Hull Description Using a Patch Hull File . . . . .	9
4.2 Control of Panelling of the Hull . . . . .	12
5 Radiation and Diffraction Computations - SM3DRadDif . . . . .	14
6 Building of Ship Model - SM3DBuildShip . . . . .	17
6.1 Hull Viscous Forces . . . . .	19
6.2 Hull Maneuvering Forces . . . . .	19
6.3 Ship Appendages – Bilge Keels, Static Foils, Skegs, and Rudders . . . . .	20
6.4 Propellers . . . . .	22
6.5 Rudder-Propeller Interaction Coefficients . . . . .	23

7	Building of Seaway Model - SM3DBuildSeaway . . . . .	24
7.1	Wave Spectra for Random Seaways . . . . .	25
7.1.1	Bretschneider Spectrum . . . . .	25
7.1.2	Three Parameter JONSWAP Spectrum . . . . .	25
7.1.3	Ochi and Hubble Six Parameter Spectrum . . . . .	26
7.1.4	Bretschneider and JONSWAP Spectrum with Cosine-Squared Spreading Function . . . . .	26
7.1.5	Ten Parameter Directional Spectrum . . . . .	27
8	Motions of Freely Maneuvering Ship in a Seaway - SM3DFreeShip . . . . .	28
9	Conclusions . . . . .	29
	References . . . . .	30
	Symbols and Abbreviations . . . . .	32
Annex A:	Files for Panelling the Hull with SM3DPanelHull . . . . .	37
A.1	Format of Input Panel Hull File . . . . .	37
A.2	Format of Input Patch Hull File . . . . .	45
A.3	Sample Input File for SM3DPanelHull . . . . .	48
A.4	Sample Patch Hull Input File for SM3DPanelHull . . . . .	50
A.5	Sample Output File for SM3DPanelHull . . . . .	60
Annex B:	Files for Radiation and Diffraction Computations with SM3DRadDif . . . . .	69
B.1	Format of Input Radiation and Diffraction File for SM3DRadDif . . . . .	69
B.2	Sample Input File for SM3DRadDif . . . . .	78
B.3	Sample Output File for SM3DRadDif . . . . .	79

Annex C: Files for Building Ship with SM3DBuildShip . . . . .	85
C.1 Format of Input Ship File for SM3DBuildShip . . . . .	85
C.2 Sample Input File for SM3DBuildShip . . . . .	117
C.3 Sample Output File for SM3DBuildShip . . . . .	120
Annex D: Files for Building a Seaway with SM3DBuildSeaway . . . . .	129
D.1 Format of Input Seaway File for SM3DBuildSeaway . . . . .	129
D.2 Sample Input File for SM3DBuildSeaway . . . . .	147
D.3 Sample Output File for SM3DBuildSeaway . . . . .	148
Annex E: Files for Simulating Motions of Freely Maneuvering Ship with SM3DFreeMo . . . . .	151
E.1 Format of Input File for Simulating Motion of a Freely Maneuvering Ship for SM3DFreeMo . . . . .	151
E.2 Sample Input File for SM3DFreeMo . . . . .	164
E.3 Sample Output File for SM3DFreeMo . . . . .	165
Distribution List . . . . .	177
Document Control Data . . . . .	181

## List of tables

---

Table 1:	ShipMo3D Plot File Formats . . . . .	4
Table 2:	SM3DPanelHull Summary . . . . .	8
Table 3:	Guidelines for Ordering of Offsets and Hull Lines for Different Hull Portions . . . . .	12
Table 4:	SM3DRadDif Summary . . . . .	14
Table 5:	SM3DBuildShip Summary . . . . .	17
Table 6:	SM3DBuildSeaway Summary . . . . .	24
Table 7:	SM3DFreeMo Summary . . . . .	28

## List of figures

---

Figure 1:	Earth-Fixed Coordinate System . . . . .	5
Figure 2:	Translating Earth Coordinate System . . . . .	6
Figure 3:	Sea Direction Relative to Ship . . . . .	6
Figure 4:	Panelled Wet Hull of Generic Frigate . . . . .	8
Figure 5:	Patch Hull of Generic Frigate . . . . .	9
Figure 6:	Hull Line within Patch Hull File, View from Aft . . . . .	10
Figure 7:	Profile of Patch Representing the Main Portion of Ship Hull, View from Port Side . . . . .	11
Figure 8:	Convention for Evaluating Hull Normal from Input Patch Data . .	11
Figure 9:	Ship Vertical Coordinates, View from Starboard . . . . .	13
Figure 10:	Heave Added Mass and Damping for Generic Frigate . . . . .	15
Figure 11:	Panelled Hull, Appendages, and Propellers of Generic Frigate from SM3DBuildShip . . . . .	18
Figure 12:	Appendage Root Location and Dihedral Angle, View from Aft . .	21

Figure 13: Dimensions for Static Foil or Rudder from Viewpoint Perpendicular to Appendage . . . . .	21
Figure 14: Long-crested Seaway with Bretschneider Spectrum, Sea State 5 . .	24

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# 1 Introduction

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This report describes the simulation of motions of a freely maneuvering ship using ShipMo3D Version 1.0 applications. ShipMo3D is an object-oriented library with associated applications for simulation of a ship in waves. ShipMo3D can compute forces on a ship and resulting motions in both the frequency and time domains. This report focusses on applications for simulation of motions in the time domain. A companion report, Reference 1, is the user manual for predicting motions in the frequency domain using ShipMo3D. For each ShipMo3D application, user input is read from an ASCII input file. Each application produces an ASCII output file, and many applications also produce graphical output.

Several reports describe the theory behind ShipMo3D, and also give verification and validation of ShipMo3D results. References 2 and 3 describe the prediction of hull hydrodynamic forces. The modelling of seaways is described in Reference 4. Reference 5 covers appendage and viscous forces, which are important for predicting lateral plane motions. The extension of ShipMo3D to freely maneuvering ships is described in Reference 6, with refinements to maneuvering forces given in Reference 7. Reference 8 gives validation results for Version 1.0 of ShipMo3D.

Section 2 of this report gives an overview of predicting motions for a freely maneuvering ship using ShipMo3D. Section 3 describes coordinate systems used for motions and ship geometry. Sections 4, 5, and 6 describe the applications SM3DPanelHull, SM3DRadDif, and SM3DBuildShip, which are used to build models of the ship hull, hull radiation and diffraction properties, and a ship including appendages. The application SM3DBuildSeaway for building seaway models is described in Section 7. Section 8 describes the application SM3DFreeMo for simulating motions of a freely maneuvering ship in the time domain. Final conclusions are given in Section 9. Annexes at the end of the report give input file descriptions and sample input and output files for the ShipMo3D applications.

## 2 Overview of Using ShipMo3D for Predicting Motions for a Freely Maneuvering Ship

---

When using ShipMo3D to simulate motions of a freely maneuvering ship, the following applications are used:

**SM3DPanelHull** Develops a model of the hull surface represented using triangular and quadrilateral panels. Also computes hydrostatic properties for the submerged portion of the hull.

**SM3DRadDif** Computes hydrodynamic added mass and radiation damping. Also computes forces due to incident and diffracted waves.

**SM3DBuildShip** Builds a complete model of the ship including all components required for motion predictions.

**SM3DBuildSeaway** Builds a model of a regular or pseudo-random seaway.

**SM3DFreeShip** Computes motions of a freely maneuvering ship in calm water or a seaway.

SM3DPanelHull creates a panel representation of the wetted hull surface based on input hull surface coordinates and load condition data. SM3DPanelHull can optionally produce a panel representation of the dry hull surface, which is required for non-linear simulations that consider the variation of the ship wetted surface with time. Ship hydrostatics and parameters for panel checking are included in output from SM3DPanelHull. Section 4 describes SM3DPanelHull in greater detail.

The wet panelled hull produced by SM3DPanelHull is used as input for radiation and diffraction computations in SM3DRadDif. SM3DRadDif produces a database file that can be used for subsequent ship motion computations. The output from SM3DRadDif should ideally encompass all combinations of ship speed, wave heading, and wave frequency that a ship will encounter. Typically computations encompassing all relevant combinations can require 2-3 hours; however, once a radiation and diffraction database has been produced it can be used for simulations in a variety of conditions. Section 5 describes SM3DRadDif in greater detail.

The radiation and diffraction database file produced by SM3DRadDif is a key input component to SM3DBuildShip. Other program inputs include descriptions of appendages (bilge keels, rudders, foils, and skegs), propellers, and hull resistance. SM3DBuildShip can build a ship model for either simulation in the time domain or for predictions in the frequency domain using the applications described in Reference 1.

SM3DBuildSeaway builds a model of a regular or pseudo-random seaway in earth-fixed coordinates. The application includes the capability to produce seaways based on input wave spectra. Section 7 describes SM3DBuildSeaway in greater detail.

SM3DFreeMo simulates motions of a freely maneuvering ship in calm water or in waves using an input ship model built by SM3DBuildShip. For the case of the ship in a seaway, the seaway is generated using SM3DBuildSeaway. Section 8 describes SM3DBuildSeaway in greater detail.

The above ShipMo3D applications use 3 main types of files. User input data are read from input files with names ending with “.inp”. Application output data for review by the user are written to output files with names ending with “.out”. Transfer of

data between applications is done using files in Python pickle format, with names ending with “.pkl”.

Each ShipMo3D application has default file names for input and output. Prefixes can be added to default file names by typing “-pPREFIX” or “--prefix=PREFIX” as command line options, where PREFIX is the specified file name prefix (e.g, the ship name). Alternatively, full input and output file names can be specified on the command line. Input file names can be specified by typing “-iINFILE” or “--input=INFILE” as command line options, where INFILE is the specified input file name. Similarly, output file names can be specified by typing “-oOUTFILE” or “--output=OUTFILE” as command line options, where OUTFILE is the specified output file name. The command line options “-h” and “--help” show any command line arguments associated with a ShipMo3D application.

ShipMo3D user input files are in ASCII format. Each input line typically begins with a tag denoting the contents of the input line. Comments can be inserted into a file using the character “#” to denote a comment line or the beginning of a comment after other input on a line. An exclamation mark “!” denotes that an input line is continued on the next line. Here is some sample input demonstrating the usage of the comment and continuation characters:

```
# Sample input from a patch hull file.
begin hullLine
    station 0    # All the offsets are on the same station.
    yOffsets    0.000 0.030 0.036 0.048 0.065 0.090 0.122 !
                0.161 0.208 0.262 0.324 0.394 0.471 0.558 !
                0.654 0.760 0.875 0.997 1.127 1.264 1.409 !
                1.560 1.718 1.881 2.049 2.300 2.512 2.725 !
                2.751
    zOffsets    4.427 4.700 4.977 5.253 5.530 5.806 6.083 !
                6.359 6.636 6.912 7.189 7.465 7.742 8.018 !
                8.295 8.571 8.848 9.124 9.401 9.677 9.954 !
                10.230 10.507 10.783 11.060 11.462 11.793 12.125 !
                12.166
end hullLine
```

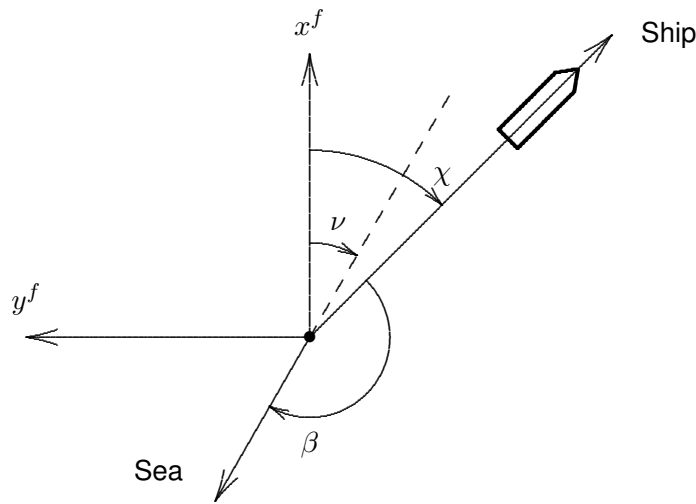
ShipMo3D applications include capabilities for plotting various entities, such as a panelled hull or results of radiation computations. Table 1 shows the various plot file formats available. Among the various plot file formats, the png format is very effective for storing complex colour plots using minimal storage space.

**Table 1:** *ShipMo3D Plot File Formats*

bmp	Windows bitmap
eps	encapsulated PostScript
gif	graphics interchange format
pdf	Portable document format
png	portable network graphics
ppm	portable pixmap
ps	PostScript
svg	scaleable vector graphics
tiff	tagged image file format
wmf	Windows metafile

### 3 Coordinate Systems

ShipMo3D uses both earth-fixed and translating earth coordinate systems. Figure 1 shows a ship in an earth-fixed coordinate system. The location of the ship centre of gravity in the horizontal plane is given by  $x^f, y^f$ . The direction  $\nu$  of incident waves is given using a “from” convention, with  $0^\circ$  representing waves from north and  $90^\circ$  representing waves from east. Ship heading  $\chi$  is given using a “to” convention, with  $0^\circ$  representing the ship heading north and  $90^\circ$  representing the ship heading east.

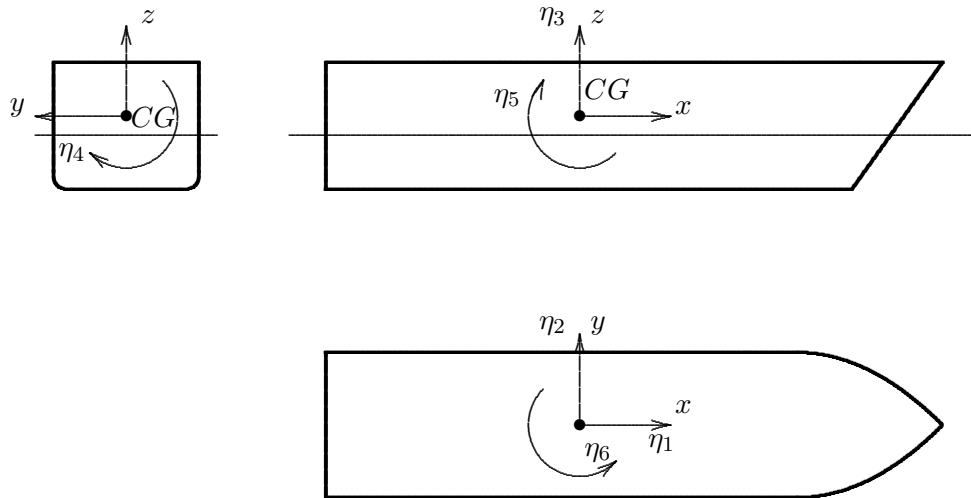


**Figure 1:** *Earth-Fixed Coordinate System*

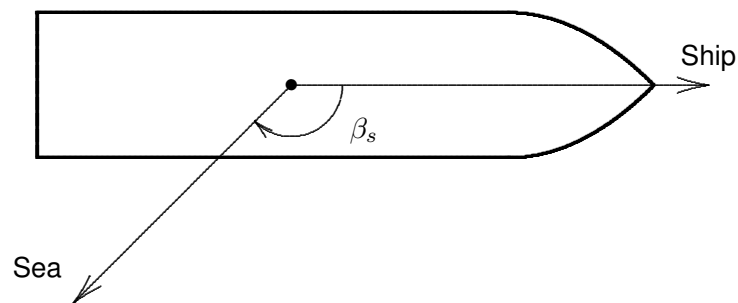
A translating earth coordinate system shown in Figure 2 is used for representing ship motions in heave, roll, pitch, and also for frequency domain applications. Heave  $\eta_3$  is the vertical displacement (+ upward) of the ship centre of gravity relative to its position when the ship is in calm water; thus, mean heave is typically near zero. Pitch  $\eta_5$  of a freely maneuvering ship is given relative to its orientation in calm water, with the pitch axis being aligned with the instantaneous heading. Ship roll  $\eta_4$  is given relative to the instantaneous heading angle  $\chi$  and pitch angle  $\eta_5$  of the moving ship.

Wave diffraction computations using SM3DRadDif are based on relative sea direction  $\beta_s$  as shown in Figure 3 ( $180^\circ$  for head seas,  $90^\circ$  for seas from port). Relative sea direction is related to ship heading and wave heading by:

$$\beta_s = \nu + 180^\circ - \chi \quad (1)$$



**Figure 2:** Translating Earth Coordinate System



**Figure 3:** Sea Direction Relative to Ship

For deflections of rudders, ShipMo3D uses a convention of positive deflection when counter-clockwise as viewed from inside the hull. Consequently, positive deflection of a typical ship rudder pointing downward will cause a ship to turn to starboard.

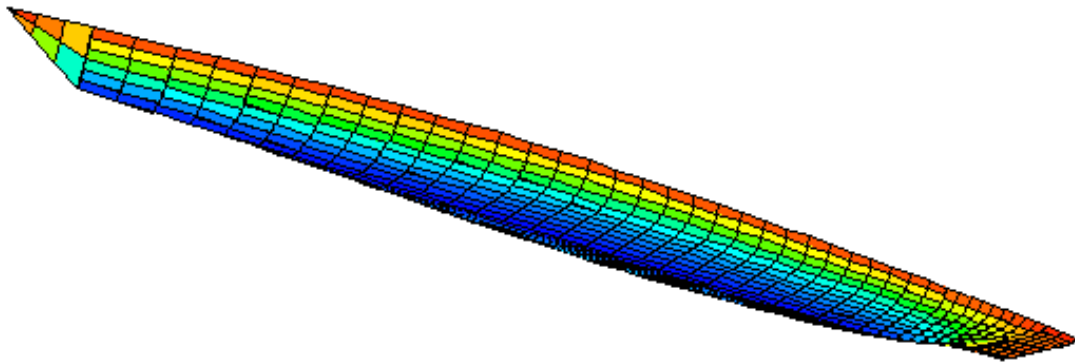
## 4 Panelling of the Ship Hull - SM3DPanelHull

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Table 2 gives a summary of application SM3DPanelHull. Figure 4 shows an example wet panel hull created by SM3DPanelHull. The panel colours indicated the elevation of the centroid of each panel relative to the waterline.

**Table 2:** *SM3DPanelHull Summary*

Purpose:	Creates a panel representation of the wet hull, and optionally of the dry hull.
Run time:	Several seconds.
Default input file:	panelHull.inp
Default output file:	panelHull.out
Sample files and file format:	Annex A
Other required input:	Patch hull file developed by user.



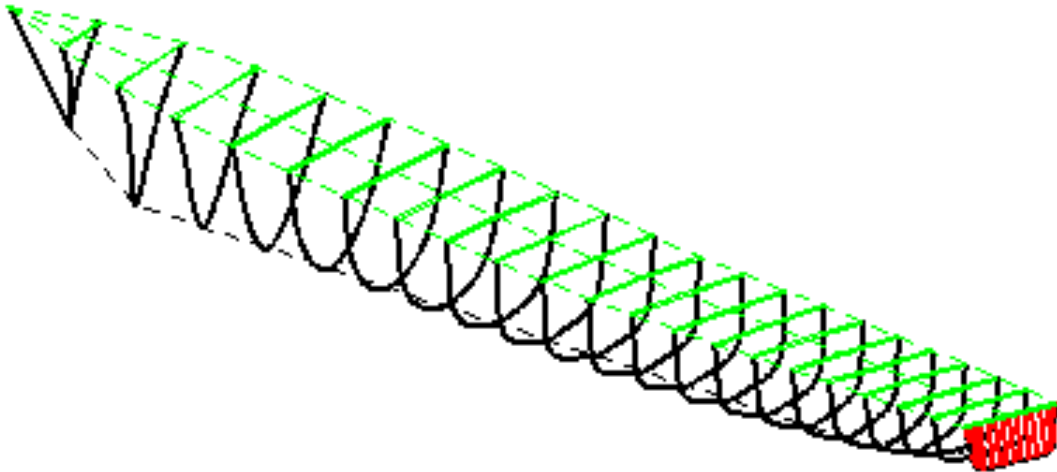
**Figure 4:** *Panelled Wet Hull of Generic Frigate*

Like all ShipMo3D applications, SM3DPanelHull reads user input from a file. The format of the main SM3DPanelHull input file is given in Annex A.1. SM3DPanelHull also reads data from a patch hull file, which has hull coordinate data. Annex A.2 describes the format of the patch hull file. The patch hull file is a reference description of the hull geometry, while the main input file is used to control how panels are generated to model the hull geometry. Ideally, the patch hull file only has to be developed once, and then can be left as a permanent representation of the hull. In contrast, the main input file can vary depending on how the user wants the hull to be panelled.



## 4.1 Hull Description Using a Patch Hull File

The patch hull file models the hull as a series of patches, with a patch being a continuous surface. For example, an ellipsoid could be modelled by a single patch. As a more complex example, Figure 5 shows the hull lines for the generic frigate used as an example for this report. The main portion of the hull is black, the deck is green, and the transom is red.



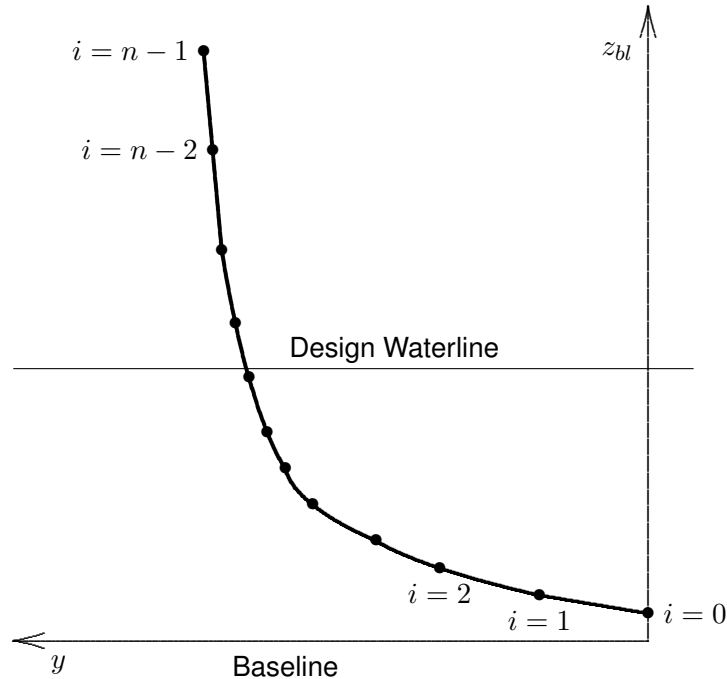
**Figure 5:** Patch Hull of Generic Frigate

Each patch is represented by a series of successive hull lines. A hull patch must have at least 2 hull lines. Each hull line must have at least 1 point. For example, a patch representing a bulbous bow could have a hull line with a single point at the front, followed by additional hull lines each having several points.

Figure 6 shows an example of a hull line on the main portion of the hull. The ship is assumed to be symmetric about the centreline; thus, offset points are only given for the port side of the hull. For a hull line intersecting the waterline, successive points should generally have increasing elevation. The hull line in Figure 6 can be described as follows in the patch hull file:

```
begin hullLine
  stations      8.0 8.0 8.0 8.0 8.0 8.0 8.0 8.0 8.0 8.0 8.0 8.0 8.0
  yOffsets      0.0 0.6 1.2 2.3 3.0 3.7 4.0 4.2 4.4 4.5 4.7 4.8 4.9
  zB1Offsets    0.3 0.4 0.5 0.8 1.1 1.5 1.9 2.3 2.9 3.5 4.3 5.4 6.5
end hullLine
```

The input record “stations” gives the station of each point on the hull line. Station 0 represents the fore perpendicular, and station 20 (or sometimes 10) typically represents the aft perpendicular. Note that the offsets on a hull line do not need to all have the same station. The input record “yOffsets” gives lateral offsets, which should all be  $\geq 0.0$  because only the port side of the hull is modelled. The input record “zBlOffsets” gives vertical offsets relative to the baseline. The baseline is a straight line, and typically represents the elevation of the keel for a substantial portion of a ship.

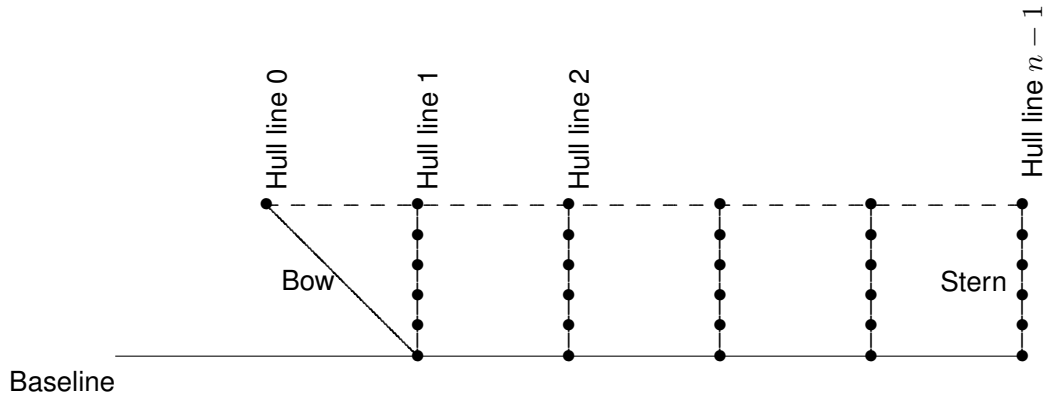


**Figure 6:** *Hull Line within Patch Hull File, View from Aft*

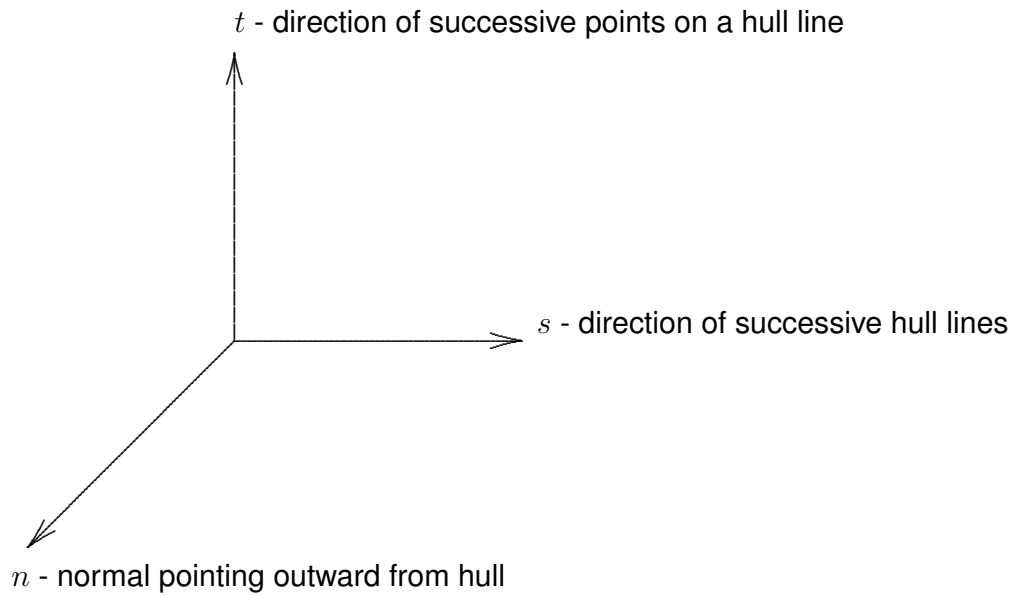
Figure 7 shows a profile of a hull patch representing the main portion of a ship hull. The patch consists of 6 hull lines, with the first hull line (index 0) representing the foremost point on the ship. For correct evaluation of hull surface normals, it is essential that hull lines be arranged in the direction indicated by Figure 8. To assist with correct panelling of the hull surface from patch data, user input for a patch includes valid ranges of normal components. ShipMo3D uses a convention of hull normals pointing outward from the hull.

In summary, the following should be observed when creating a patch hull file:

- For non-horizontal hull lines, the order of offset points should go from lower to higher elevation.
- The order of successive hull lines must be given to satisfy the hull normal convention of Figure 8.



**Figure 7:** Profile of Patch Representing the Main Portion of Ship Hull, View from Port Side



**Figure 8:** Convention for Evaluating Hull Normal from Input Patch Data

Table 3 gives guidelines for patch representations of different parts of a hull.

**Table 3:** *Guidelines for Ordering of Offsets and Hull Lines for Different Hull Portions*

Main hull surface	Offsets on a hull line go from keel to port deck edge. Successive hull lines go from bow to stern.
Deck	Offsets on a hull line go from port deck edge to centreline. Successive hull lines go from bow to stern.
Transom	Offsets on a hull line go from bottom to deck edge. Successive hull lines go from port edge to centreline.

If the patch hull is going to be used to build both wet and dry panelled hulls, then the patch hull should represent a closed volume. If only a wet panelled hull will be built, then it is not necessary to enclose the dry portion of the hull.

Each input patch includes an optional input parameter to limit the maximum size of panels representing the patch. This parameter can be useful for portions of the hull surface with smaller curvature radii (e.g., bulbous bows) that require smaller panels than the remainder of the hull surface.

## 4.2 Control of Panelling of the Hull

The main input file for SM3DPanelHull controls panelling of the hull described by the patch hull file. SM3DPanelHull panels the wet hull, and optionally panels the dry hull. Figure 9 shows the ship vertical coordinates. When giving the input load condition, the user can provide one of the following sets of input data:

- draft of baseline at midships (draftBIMid) and trim of the baseline by the stern (trimBIStern),
- displacement of the ship (dispTonnes) and the longitudinal location of the centre of gravity (lcgAftFp).

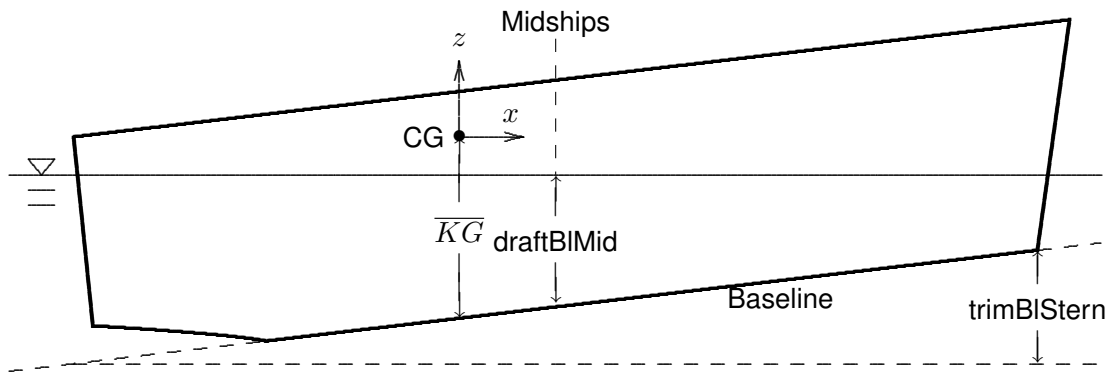
If the displacement and LCG are provided as input, then an iterative procedure is used to determine the combination of draft and trim that produces a wet panelled hull with the correct displacement and LCG.

SM3DPanelHull fits smooth B-splines to input points on hull lines. For modelling of hull surfaces, the user can choose linear interpolation of points between hull lines or fitting of bi-directional B-spline surfaces to hull lines. Fitting of bi-directional B-spline surfaces provides a more accurate representation to a hull, but can cause problems if an insufficient number of input hull lines is available to represent a surface, particularly in cases of surfaces with high rates of curvature.

The nominal panel area nomPanelArea is one of the most important input parameters for SM3DPanelHull. For typical ship geometries, it is recommended that nom-

PanelArea be selected such that the wet portion of the hull surface is represented by 200-500 panels on the port side.

SM3DPanelHull can produce plots of the panelled hull such as the example in Figure 4. The SM3DPanelHull output also gives values for checking the quality of the panelled hull mesh.



**Figure 9:** Ship Vertical Coordinates, View from Starboard

## 5 Radiation and Diffraction Computations - SM3DRadDif

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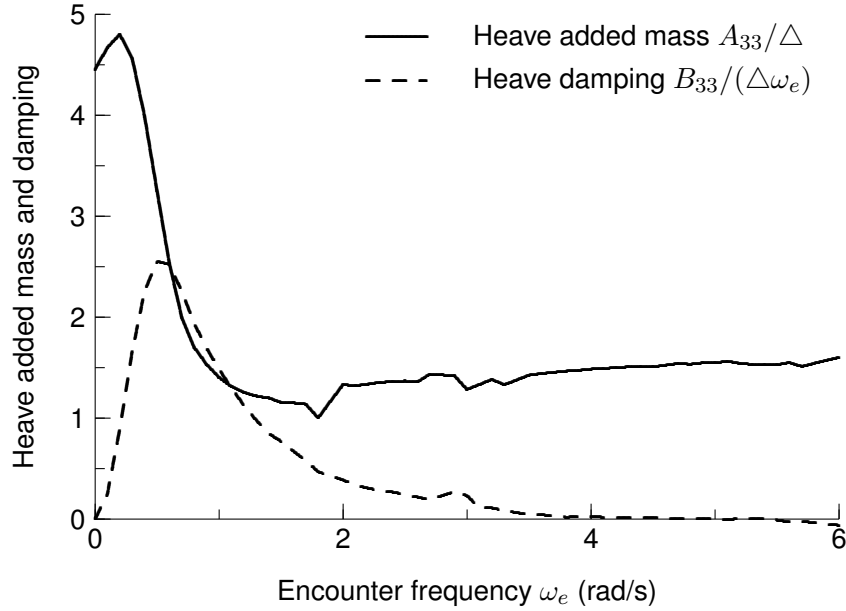
Table 4 gives a summary of application SM3DRadDif, which computes hydrodynamic forces due to added mass, wave radiation damping, and wave excitation from incident and diffracted waves. Computations are performed in the frequency domain; however, results can be transformed to the time domain for subsequent computations. Due to the complexities of ship hydrodynamic computations, SM3DRadDif is considered to be the most computationally intensive of ShipMo3D applications. The approach used for computing hull hydrodynamic forces is described in detail in References 2 and 3.

**Table 4:** *SM3DRadDif Summary*

Purpose:	Creates a database of added mass, radiation damping, and wave excitation forces for the ship in all conditions to be encountered in subsequent motion computations.
Run time:	Several minutes without wave diffraction computations. Up to several hours with full wave diffraction computations.
Default input file:	radDif.inp
Default output file:	radDif.out
Sample files and file format:	Annex B
Other required input:	Wet panelled hull created by SM3DPanelHull.

SM3DRadDif computes hull added mass and radiation damping for a range of encounter frequencies specified by user input. Figure 10 shows computed added mass and damping for a naval frigate. The input encounter frequencies should be selected such that the variation of added mass and damping with encounter frequency is captured for all 6 degrees of freedom. The main output file from SM3DRadDif and optional plot files of hydrodynamic coefficients can be examined to determine whether a suitable range of encounter frequencies has been used. Both the output file and plot files give non-dimensional coefficients with magnitude relative to the ship inertia force amplitude during sinusoidal motion. At the highest encounter frequency, added mass should approach its infinite frequency value and damping should approach zero. For naval frigates, an encounter frequency range of 0.1, 0.2, ..., 6.0 rad/s is suitable. Froude scaling can be applied to determine suitable encounter frequency ranges for ships of other sizes.

Like most hydrodynamic panel codes, SM3DRadDif will have irregular frequencies associated with each wet panel hull. An irregular frequency is a frequency at which the



**Figure 10:** Heave Added Mass and Damping for Generic Frigate

solution of hull source strengths and hull associated velocity potentials gives unreliable results. To better understand irregular frequencies, note that source strengths on the hull are solved by satisfying the following:

$$[D] \{\sigma\} = \left\{ \frac{\partial \phi}{\partial n} \right\} \quad (2)$$

where  $[D]$  is the influence matrix giving hull normal velocity from source strengths,  $\{\sigma\}$  is the vector of source strengths to be solved, and  $\{\partial \phi / \partial n\}$  is the vector of known normal velocities on the hull surface. At irregular frequencies, the solution of source strengths  $\{\sigma\}$  is highly sensitive to variations in elements of the influence matrix  $[D]$ . Variations in computed source strengths  $\{\sigma\}$  will lead to variations in computed velocity potentials  $\{\phi\}$ , which are evaluated using the following:

$$\{\phi\} = [E] \{\sigma\} \quad (3)$$

where  $[E]$  is the influence matrix giving velocity potential from source strength.

SM3DRadDif uses lateral symmetry when solving for hydrodynamic coefficients; thus, longitudinal modes have one set of irregular frequencies and lateral modes have another set of irregular frequencies. When examining plots of added mass and/or damping versus encounter frequency, large local variations occur at irregular frequencies. Similarly, an irregular frequency will usually have a large local increase in the condition number of matrix  $[D]$  from Equation (2). To prevent SM3DRadDif from using

computations at irregular frequencies, user input can specify encounter frequencies to be removed. User input can also specify threshold matrix condition numbers indicating the presence of irregular frequencies. The threshold matrix condition numbers can be determined by examining the results of an initial SM3DRadDif run.

The most time consuming part of running SM3DRadDif is usually the evaluation of wave diffraction forces. Note that wave diffraction forces should be evaluated for all combinations of ship speed, heading, and wave frequency that a ship is likely to encounter. For a naval frigate, an input ship speed range of 0, 5, 10, ..., 40 knots can be used. Note that the upper speed should include the influence of wave-induced surge motion for a freely maneuvering ship. An input relative sea direction range of 0, 15, 30, ..., 180 degrees is suitable for any ship. An input wave frequency range of 0.1, 0.2, 0.3, ..., 2.0 rad/s usually is sufficient for the range of seaways encountered by full-scale ships.

SM3DRadDif includes an option for suppressing diffraction computations. The primary purpose of this option is to permit checking for irregular frequencies before proceeding with time-consuming diffraction computations. It is suggested that the following sequence be used when using SM3DRadDif for a new wet panel hull:

1. Run SM3DRadDif with diffraction computations suppressed.
2. Check output for irregular frequencies, and re-run SM3DRadDif specifying encounter frequencies to be removed and/or appropriate thresholds on matrix condition numbers.
3. Check revised output for irregular frequencies. If irregular frequencies still exist, repeat step 2 with revised encounter frequencies to be removed and/or matrix condition numbers. If no irregular frequencies remain, then run SM3DRadDif including diffraction computations.

As indicated above, SM3DRadDif can produce plots of non-dimensional hydrodynamic coefficients and matrix condition numbers. The plot files have root names of “surgeCo”, “swayCo”, “heaveCo”, “rollCo”, “pitchCo”, and “yawCo”, “normCo-Long”, “normCoLat”, and “condition”. The files names can have a prefix specified by the user, and have suffixes dependent on the plot file format.



## 6 Building of Ship Model - SM3DBuildShip

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Table 5 gives a summary of application SM3DBuildShip, which creates a database of all relevant ship properties used for computation of ship motions. Figure 11 shows a sample view of a hull and appendages produced by SM3DBuildShip. SM3DBuildShip can build ship models for simulation in the time domain or for predictions in the frequency domain.

**Table 5:** *SM3DBuildShip Summary*

Purpose:	Creates a database of ship properties influencing hydrodynamic forces, including hull radiation and diffraction, hull resistance, hull maneuvering, appendages, and propellers.
Run time:	Several seconds, or several minutes if propeller RPMs are to be determined for specified ship speeds.
Default input file:	buildShip.inp
Default output file:	buildShip.out
Sample files and file format:	Annex C
Other required input:	Hull radiation and diffraction database created by SM3DRadDif. Dry panel hull file if nonlinear buoyancy and incident wave forces will be used for ship motion predictions.

A dry panel hull file is among the optional input parameters for SM3DBuildShip. Note that this option must be used if ship motion predictions with SM3DFreeMo will include nonlinear buoyancy and incident wave forces.

SM3DBuildShip includes optional input for correction to the metacentric height of the ship. This parameter can be set to a negative value to model the influence of partially filled tanks on roll stiffness.

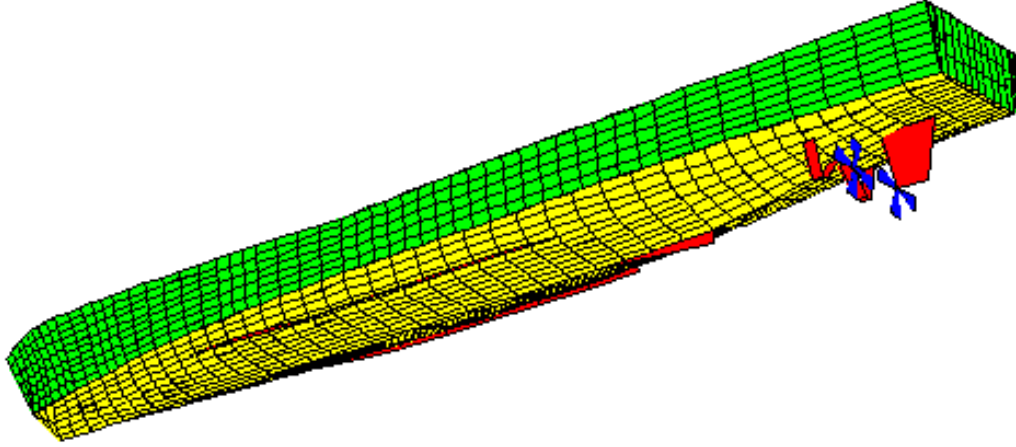
Input radii of gyration for roll, pitch, and yaw are given as values for the dry ship, and do not include the influence of ship added mass. Estimates of radii of gyration are as follows:

$$r_{44} \approx 0.4 B_{max} \quad (4)$$

$$r_{55} \approx 0.25 L \quad (5)$$

$$r_{66} \approx 0.25 L \quad (6)$$

where  $r_{44}$  is roll radius of gyration,  $r_{55}$  is pitch radius of gyration, and  $r_{66}$  is yaw radius of gyration. If the ship natural roll period is known but the ship roll gyradius



**Figure 11:** *Panelled Hull, Appendages, and Propellers of Generic Frigate from SM3DBuildShip*

is unknown, it is recommended that SM3DBuildShip be run with several different input gyradius values to determine which value produces the correct natural roll period.

For time domain predictions of ship motions, wave radiation forces are evaluated using retardation functions. The retardation functions are determined using transforms of wave radiation forces in the frequency domain. SM3DBuildShip reads input for the time interval and maximum value of retardation functions. The time interval should be sufficiently fine to capture the variation of retardation functions, and the maximum value should encompass the time when retardation functions approach zero. For a naval frigate, a time interval of 0.2 s and maximum time of 20 s provide good representation of retardation functions. Suitable values for other ships can be estimated using Froude scaling as follows:

$$\Delta\tau \approx 0.05\sqrt{\frac{L}{g}} \quad (7)$$

$$\tau_{max} \approx 5\sqrt{\frac{L}{g}} \quad (8)$$

where  $\Delta\tau$  is the time interval and  $\tau_{max}$  is the maximum time for retardation functions.

## 6.1 Hull Viscous Forces

Viscous hull force input is given in the form of hull resistance coefficients for various speeds, an eddy-making roll damping coefficient, and a lateral drag coefficient. References 5, 6 and 7 give further discussion of hull viscous forces. Hull resistance force is evaluated as follows:

$$F_1^{resist} = -\frac{1}{2} \rho U |U| A_w C_{Dx}(U) \quad (9)$$

where  $U$  is ship speed,  $A_w$  is wetted surface area, and  $C_{Dx}$  is the hull resistance coefficient.

Hull eddy-making damping at zero speed is evaluated by:

$$F_4^{hull-eddy} = -\frac{1}{2} \rho |\dot{\eta}_4| \eta_4 C_{eddy}^{hull} \frac{1}{2} \int_{S_{hull}} n_4^2 \sqrt{y^2 + z^2} dS \quad (10)$$

where  $C_{eddy}^{hull}$  is the hull eddy-making coefficient for roll,  $S_{hull}$  is the wetted hull surface, and  $n_4$  is the roll normal. At non-zero speed, a speed correction factor is applied. The hull eddy-making coefficient has a default value of 1.17, the drag coefficient for a flat plate moving perpendicular to flow. Note that hull eddy-making damping is typically a small fraction of roll damping; thus, roll motion predictions are usually not very sensitive to the value of the hull eddy-making coefficient.

ShipMo3D can model hull cross-flow drag as follows:

$$F_2^{cross} = \frac{1}{2} \rho \sum_{i=1}^{N_{seg}} v^{cross}(\bar{x}_{Ay-i}) |v^{cross}(\bar{x}_{Ay-i})| A_{y-i} C_{Dy} \quad (11)$$

where  $N_{seg}$  is the number of longitudinal segments along the hull for evaluating cross-flow drag,  $v^{cross}$  is cross-flow velocity,  $\bar{x}_{Ay-i}$  is the  $x$  centroid of the profile area of segment  $i$ ,  $A_{y-i}$  is the profile area of segment  $i$ , and  $C_{Dy}$  is the hull cross-flow drag coefficient. Within ShipMo3D, the hull cross-flow drag coefficient is often set to zero because cross-flow drag forces are instead modelled using nonlinear maneuvering coefficients. If nonlinear maneuvering coefficients are not used to model cross-flow drag, then the cross-flow drag coefficient can be set to a value of approximately 1.0.

## 6.2 Hull Maneuvering Forces

References 6 and 7 provide background information for prediction of hull maneuvering forces. The user can provide input hull maneuvering coefficients or can use values predicted based on the method of Inoue et al. [9]. As discussed in Reference 6, there is significant uncertainty associated with hull maneuvering coefficients and resulting

hull maneuvering predictions. Most notably, the uncertainty in the linear yaw-yaw coefficient  $N_r$  can lead to significant uncertainty in predicted ship turning circle characteristics. Consequently, it is recommended that the best possible estimates of hull maneuvering force coefficients be provided as input. If maneuvering force coefficients are unavailable but maneuvering trial data exist, then one can consider modifying the yaw-yaw coefficient  $N_r$  to obtain good agreement between observed and predicted turning circles.

### 6.3 Ship Appendages – Bilge Keels, Static Foils, Skegs, and Rudders

Ship appendages significantly influence ship motions in sway, roll, and yaw. SM3D-BuildShip currently models bilge keels, static foils (e.g., propeller shaft brackets), skegs, and rudders. If modelling of roll stabilizer fins is required, then these can be input as additional rudders. References 5 and 6 discuss treatment of appendage forces.

Bilge keels and skegs are considered to have long chord lengths, with input dimensions provided at several longitudinal locations along the hull. Static foils and rudders are considered to have short chord lengths, with input dimensions provided at only a single longitudinal location. Figure 12 shows an appendage attached to a hull. The convention for dihedral angle is  $0^\circ$  for the appendage pointing to port and  $90^\circ$  for the appendage point upward. Rudders and skegs typically have dihedral angles of  $-90^\circ$ . Port bilge keels typically have dihedral angles of approximately  $-45^\circ$ , and starboard bilge keels typically have dihedral angles of approximately  $-135^\circ$ . Figure 13 shows dimensions for a static foil or rudder, where  $c_{root}$  is the root chord length,  $c_{tip}$  is the tip chord length, and  $s$  is the span.

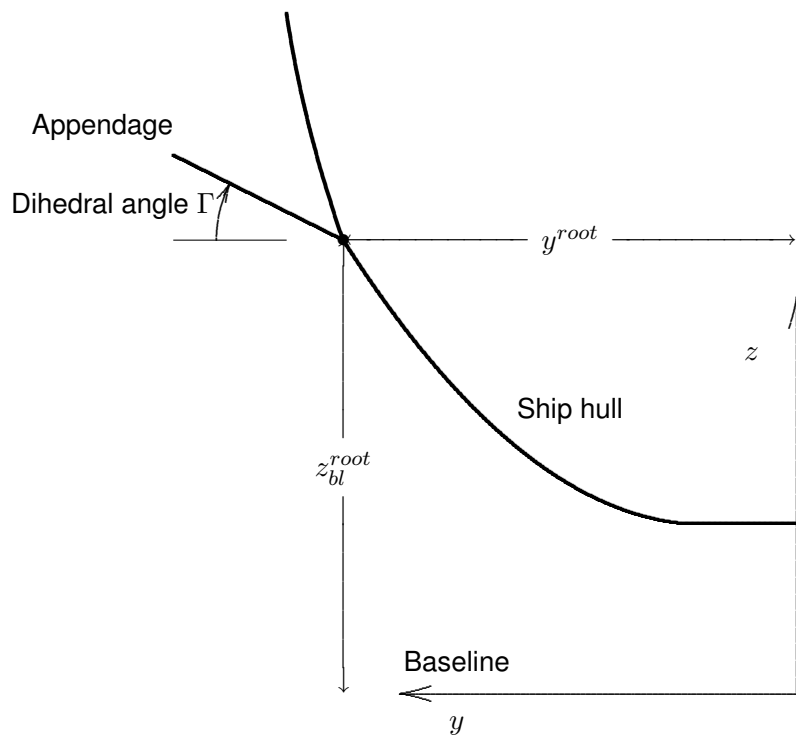
When predicting lateral plane ship motions, one of the greatest challenges is accurate prediction of viscous roll damping from bilge keels. It is recommended that Ikeda's method [5] be used for predicting viscous bilge keel damping.

To simplify input and reduce the possibility of input errors, the user can specify that input is being given for a pair of appendages. The user then provides input data for only the port appendage. SM3DBuildShip then generates a port appendage first, and a starboard appendage second.

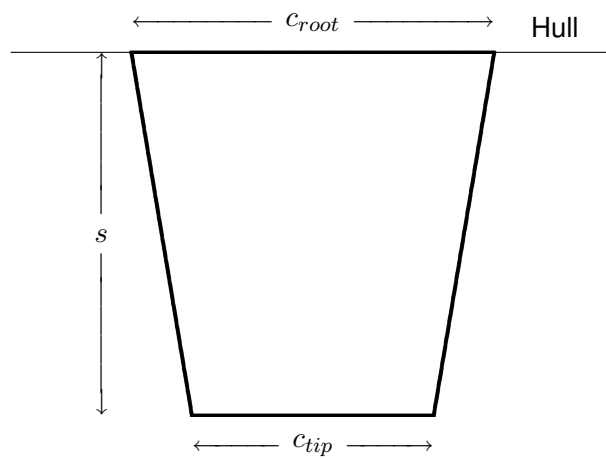
For rudders, SM3DBuildShip requires input autopilot data. The rudder response characteristics are modelled as follows:

$$\ddot{\delta}^{rudder} + 2 \zeta_\delta \omega_\delta^{rudder} \dot{\delta}^{rudder} + \omega_\delta^2 \delta^{rudder} = \omega_\delta^2 \delta_C^{rudder} \quad (12)$$

where  $\ddot{\delta}^{rudder}$  is rudder acceleration,  $\zeta_\delta$  is the nondimensional damping response constant,  $\omega_\delta$  is the rudder response natural frequency,  $\dot{\delta}^{rudder}$  is rudder velocity, and



**Figure 12:** Appendage Root Location and Dihedral Angle, View from Aft



**Figure 13:** Dimensions for Static Foil or Rudder from Viewpoint Perpendicular to Appendage

$\delta_C^{rudder}$  is command rudder angle. Rudder deflections have a convention of positive for counter-clockwise deflection viewed from inside the hull. The rudder command angle is determined by input autopilot gains and ship motions in earth-fixed axes:

$$\delta_C^{rudder} = \sum_{j=1}^6 \left[ k_{\delta j}^P (\eta_j^f - \eta_{Cj}^f) + k_{\delta j}^I \int_0^{\tau_{max}^{rudder}} (\eta_j^f(t - \tau) - \eta_{Cj}^f) d\tau + k_{\delta j}^D \dot{\eta}_j^f \right] \quad (13)$$

where  $k_{\delta j}^P$  is the proportional gain for mode  $j$ ,  $\eta_j^f$  is the motion displacement in earth-fixed axes for mode  $j$ ,  $\eta_{Cj}^f$  is the command motion displacement for mode  $j$ ,  $k_{\delta j}^I$  is the integral gain for mode  $j$ ,  $\tau_{max}^{rudder}$  is the integration duration,  $t$  is the current time,  $\tau$  is the time delay for integration,  $k_{\delta j}^D$  is the derivative gain for mode  $j$ , and  $\dot{\eta}_j^f$  is the motion velocity in earth-fixed axes for mode  $j$ . Within SM3DBuildShip, input autopilot gains should always be given in terms of earth-fixed axes.

The simulation of a rudder control system including autopilot requires selection of suitable input values. For a US Coast Guard cutter representative of modern frigate design, Smith [10] indicates a maximum rudder deflection of 35 degrees and maximum rudder rate of 3 degrees per second. For modelling of a conventional downward rudder using ShipMo3D, the yaw gain and yaw velocity gain for an autopilot will typically have values less than or equal to zero if the autopilot is being used for coursekeeping.

The natural frequency of rudder control systems is often significantly greater than the natural frequencies for ship motion modes; thus, a smaller time step is often required for rudder motions than for ship motions during time domain simulations. The user can specify a maximum allowable time step for rudder motions to ensure reliable prediction of rudder motions.

## 6.4 Propellers

SM3DBuildShip can model fixed pitch propellers as described in Reference 6. The thrust created by the propeller is modelled as:

$$F^{prop} = (1 - t_{prop}) \rho n_{prop}^2 D_{prop}^4 K_T(J_{prop}) \quad (14)$$

where  $t_{prop}$  is the propeller thrust deduction coefficient,  $n_{prop}$  is the propeller speed in revolutions per second, and  $D_{prop}$  is the propeller diameter. The propeller thrust coefficient  $K_T$  is a function of the advance coefficient  $J_{prop}$ , which is given by:

$$J_{prop} = \frac{U (1 - w_{prop})}{n_{prop} D_{prop}} \quad (15)$$

where  $w_{prop}$  is the propeller wake fraction. The following quadratic function is used to model the relationship between propeller thrust coefficient  $K_T$  and advance coefficient

$J_{prop}$ :

$$K_T = K_T^0 + K_T^J J_{prop} + K_T^{JJ} J_{prop}^2 \quad (16)$$

where  $K_T^0$ ,  $K_T^J$ , and  $K_T^{JJ}$  are specified coefficients. The user can provide  $K_T^0$ ,  $K_T^J$ , and  $K_T^{JJ}$  as input values, or these values can be computed based on 3 input pairs of  $J_{prop}$  and  $K_T(J_{prop})$ .

To simplify input and reduce the possibility of input errors, the user can specify that input is being given for a pair of propellers. The user then provides input data for only the port propeller. SM3DBuildShip then generates a port propeller first, and a starboard propeller second.

The propeller control response is modelled very similarly to the rudder control system, with the rate of change of propeller RPM being modelled as follows:

$$R\ddot{M}^{prop} = \omega_{RPM}^2 (RPM_C^{prop} - RPM^{prop}) - 2\zeta_{RPM} \omega_{RPM} R\dot{M}^{prop} \quad (17)$$

where  $R\ddot{M}^{prop}$  is the second derivative with respect to time of propeller RPM,  $\omega_{RPM}$  is the RPM response natural frequency,  $RPM_C^{prop}$  is command propeller RPM,  $RPM^{prop}$  is propeller RPM,  $\zeta_{RPM}$  is RPM response damping, and  $R\dot{M}^{prop}$  is the first derivative with respect to time of propeller RPM. The user can specify a maximum allowable time step for simulation of propeller RPM in a manner similar to that used for rudder deflection.

## 6.5 Rudder-Propeller Interaction Coefficients

For rudders placed aft of propellers, flow from propellers can significantly increase the effectiveness of the rudders. This effect is modelled using rudder-propeller interaction coefficients, as described in Reference 7, which supercedes the treatment presented in Reference 6. The rudder-propeller interaction coefficient represents the effective fraction of the rudder area that lies within the propeller slipstream. For a rudder immediately behind a propeller with the rudder locating entirely within the propeller slipstream, the rudder-propeller interaction coefficient will approach its limiting value of 1.0. If a rudder is located away from the propeller slipstream, then the rudder-propeller interaction coefficient will approach zero.

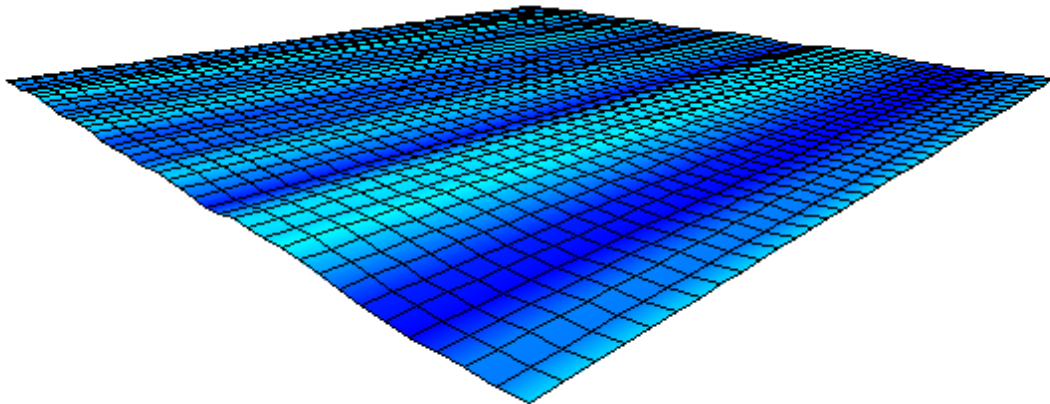
## 7 Building of Seaway Model - SM3DBuildSeaway

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Table 6 gives a summary of application SM3DBuildSeaway, which creates a regular or random seaway in earth-fixed coordinates. Figure 14 shows a sample view of a long-crested random produced by SM3DBuildSeaway.

**Table 6:** *SM3DBuildSeaway Summary*

Purpose:	Creates a regular or random seaway in earth-fixed coordinates.
Run time:	Several seconds.
Default input file:	buildSeaway.inp
Default output file:	buildSeaway.out
Sample files and file format:	Annex D



**Figure 14:** *Long-crested Seaway with Bretschneider Spectrum, Sea State 5*

SM3DBuildSeaway represents random seaways using superposition of a number of sinusoidal wave components. Both unidirectional and multidirectional random seaways can be produced. For a random seaway, the range of wave frequencies should be sufficient to encompass almost all energy within the wave spectrum. For ocean wave spectra, a frequency range of 0.2 – 2.0 rad/s is recommended.



## 7.1 Wave Spectra for Random Seaways

SM3DBuildSeaway can produce random seaways based on input wave spectra. Reference 4 describes modelling of seaways in detail. Wave spectra available in SM3DBuildSeaway are provided here for reference. For point wave spectra (i.e., non-directional spectra), ShipMo3D uses units of  $\text{m}^2/(\text{rad/s})$  for spectral density. For directional wave spectra, ShipMo3D uses units of  $\text{m}^2/(\text{rad/s})/\text{deg}$  for directional spectral density.

### 7.1.1 Bretschneider Spectrum

The Bretschneider spectrum is the most commonly used model of point wave spectra in the open ocean. Based on the 15th International Towing Tank Conference (ITTC) [11], the formulation for the Bretschneider spectrum is:

$$S_{\omega_I}(\omega_I) = \frac{486.0 H_s^2}{T_p^4 \omega^5} \exp \left[ \frac{-1948.2}{T_p^4 \omega_I^4} \right] \quad (18)$$

The above spectrum is defined in terms of peak wave period  $T_p$ . For a Bretschneider spectrum, the following relations exist with the average and zero-crossing wave periods:

$$T_1 = 0.773 T_p \quad (19)$$

$$T_z = 0.710 T_p \quad (20)$$

### 7.1.2 Three Parameter JONSWAP Spectrum

The JONSWAP spectrum models relatively high-peaked point spectra typically encountered in fetch-limited regions [11]. The JONSWAP spectrum is obtained by multiplying the Bretschneider spectrum by a peak enhancement factor accounting for fetch-limited conditions, giving the following [12]:

$$S_{\omega_I}(\omega_I) = \alpha^* H_s^2 \frac{\omega_p^4}{\omega^5} \exp \left[ -1.25 \frac{\omega_p^4}{\omega^4} \right] \gamma^\kappa \quad (21)$$

$$\kappa = \exp \left[ \frac{-(\omega - \omega_p)^2}{2\sigma^2 \omega_p^2} \right] \quad (22)$$

$$\sigma = \begin{cases} 0.07 & \text{for } \omega \leq \omega_p \\ 0.09 & \text{for } \omega > \omega_p \end{cases} \quad (23)$$

where  $\omega_p$  is the peak wave frequency and  $\gamma$  is an input spectral peak parameter. Goda [13] derived the following approximate expression for the normalization term  $\alpha^*$ :

$$\alpha^* = \frac{0.0624}{0.230 + 0.0336 \gamma - 0.185/(1.9 + \gamma)} \quad (24)$$

The JONSWAP spectrum is often presented as a two parameter spectrum, with the spectral peak parameter  $\gamma$  having a default value of 3.3.

### 7.1.3 Ochi and Hubble Six Parameter Spectrum

The Ochi and Hubble 6 parameter point spectrum [14] models collinear swell and sea components as follows:

$$S_{\omega_I}(\omega_I) = \frac{1}{4} \sum_{i=1}^2 \frac{\left[\left(\frac{4\lambda_i+1}{4}\right) \omega_{p-i}^4\right]^{\lambda_i} h_{s-i}^2 \exp\left[-\left(\frac{4\lambda_i+1}{4}\right) \left(\frac{\omega_{p-i}}{\omega}\right)^4\right]}{\Gamma(\lambda_i) \omega^{(4\lambda_i+1)}} \quad (25)$$

where  $\lambda_i$ ,  $h_{s-i}$ , and  $\omega_{p-i}$  are the spectral shape parameter, significant wave height, and peak frequency for component  $i$ . The term  $\Gamma(\lambda_i)$  is the Gamma function with argument  $\lambda_i$ . If only one of the two components is considered and the shape parameter  $\lambda_i$  equals one, then the six parameter spectrum is equivalent to the Bretschneider spectrum.

### 7.1.4 Bretschneider and JONSWAP Spectrum with Cosine-Squared Spreading Function

A directional wave spectrum can be most easily modelled by multiplying a point spectrum by a directional spreading function as follows:

$$S_{\omega_I, \nu}(\omega_I, \nu) = S_{\omega_I}(\omega_I) G(\nu) \quad (26)$$

where  $G(\nu)$  is a directional spreading function. ShipMo3D can apply a cosine-squared spreading function to a Bretschneider or JONSWAP spectrum. The form of the spreading function is as follows:

$$G(\nu) = \frac{1}{\theta_s} \cos^2\left(\frac{\nu - \bar{\nu}}{\theta_s} \frac{\pi}{2}\right) \quad \text{for } |\nu - \bar{\nu}| \leq \theta_s \quad (27)$$

$$G(\nu) = 0 \quad \text{for } |\nu - \bar{\nu}| > \theta_s \quad (28)$$

where  $\bar{\nu}$  is the principal wave direction and  $\theta_s$  is the spreading angle in degrees. A spreading angle of 90 degrees is often used for seakeeping computations. The spreading function given in Equation (27) has units of  $\text{deg}^{-1}$  when the terms  $\nu$ ,  $\bar{\nu}$ , and  $\theta_s$  are given in units of degrees. Although Equations (27) and (28) are defined using directions  $\nu$  and  $\bar{\nu}$  based in earth-fixed axes, they can also be easily defined in terms of relative sea direction  $\beta_s$ .

### 7.1.5 Ten Parameter Directional Spectrum

Directional seas can be most apparent when sea and swell components are similar in magnitude and are approaching from different directions. The ten parameter spectrum developed by Hogben and Cobb [15] is a directional extension of the Ochi and Hubble six parameter spectrum, with each of the swell and sea components being multiplied by its own directional spreading function as follows:

$$M_i(\nu) = A(P_i) \cos^{2P_i} \left( \frac{\pi}{180^\circ} \frac{\nu - \bar{\nu}_i}{2} \right) \text{ for } i = 1, 2 \quad (29)$$

where  $P_i$  and  $\bar{\nu}_i$  are the directional spreading parameter and mean direction (from) for component  $i$ . The normalization factor  $A(P_i)$  is expressed as:

$$A(P_i) = \frac{2^{(2P_i-1)} \Gamma^2(P_i + 1)}{180^\circ \Gamma(2P_i + 1)} \quad i = 1, 2 \quad (30)$$

where  $\Gamma(2P_i + 1)$  is the Gamma function with argument  $2P_i + 1$ . The above equations are based on parameters  $\nu$  and  $\bar{\nu}_i$  being in units of degrees, and each spreading function  $M_i(\nu)$  having units of  $\text{degrees}^{-1}$ .

## 8 Motions of Freely Maneuvering Ship in a Seaway - SM3DFreeShip

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Table 7 gives a summary of application SM3DFreeMo for simulating motions in the time domain of a freely maneuvering ship. Input for SM3DFreeMo includes initial conditions, and commands that can be used to set propeller RPM and rudder mode (autopilot or input rudder angle) during a simulation.

**Table 7:** *SM3DFreeMo Summary*

Purpose:	Simulations motions in the time domain of a freely maneuvering ship.
Run time:	Typically faster than real-time.
Default input file:	freeMo.inp
Default output file:	freeMo.out
Sample files and file format:	Annex E

## 9 Conclusions

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ShipMo3D user applications are now available for simulating motions of a freely maneuvering ship in calm water and in waves. A separate user manual [1] describes frequency domain prediction of ship motions in waves.

# References

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- [1] McTaggart, K.A. (2007). ShipMo3D Version 1.0 User Manual for Frequency Domain Analysis of Ship Seakeeping in a Seaway. (DRDC Atlantic TM 2007-171). Defence Research and Development Canada - Atlantic.
- [2] McTaggart, K.A. (2002). Three Dimensional Ship Hydrodynamic Coefficients Using the Zero Forward Speed Green Function. (DRDC Atlantic TM 2002-059). Defence Research and Development Canada - Atlantic.
- [3] McTaggart, K.A. (2003). Hydrodynamic Forces and Motions in the Time Domain for an Unappended Ship Hull. (DRDC Atlantic TM 2003-104). Defence Research and Development Canada - Atlantic.
- [4] McTaggart, K.A. (2003). Modelling and Simulation of Seaways in Deep Water for Simulation of Ship Motions. (DRDC Atlantic TM 2003-190). Defence Research and Development Canada - Atlantic.
- [5] McTaggart, K.A. (2004). Appendage and Viscous Forces for Ship Motions in Waves. (DRDC Atlantic TM 2004-227). Defence Research and Development Canada - Atlantic.
- [6] McTaggart, K.A. (2005). Simulation of Hydrodynamic Forces and Motions for a Freely Maneuvering Ship in a Seaway. (DRDC Atlantic TM 2005-071). Defence Research and Development Canada - Atlantic.
- [7] McTaggart, K.A. (2008). Improved Maneuvering Forces and Autopilot Modelling for the ShipMo3D Ship Motion Library. (DRDC Atlantic TM 2008-162). Defence Research and Development Canada - Atlantic.
- [8] McTaggart, K.A. (2007). Validation of ShipMo3D Version 1.0 User Applications for Simulation of Ship Motions. (DRDC Atlantic TM 2007-173). Defence Research and Development Canada - Atlantic.
- [9] Inoue, S., Hirano, M., and Kijima, K. (1981). Hydrodynamic Derivatives on Ship Manoeuvring. *International Shipbuilding Progress*, **28**(321), 112–125.
- [10] Smith, T.C. (1999). T-ADC(X) Maneuvering in Waves Study Using FREDYN. (Report NSWCCD-50-TR-1999\038). NSWCCD.
- [11] (1978). ITTC Seakeeping Committee Report. In *15th International Towing Tank Conference*, Vol. 1, pp. 55–114. The Hague.
- [12] Chakrabarti, S.K. (1987). *Hydrodynamics of Offshore Structures*, Springer-Verlag.
- [13] Goda, Y. (1979). A Review of Statistical Interpretation of Wave Data. (Report 18 (1)). Port and Harbour Research Institute.
- [14] Ochi, M.K. and Hubble, E.N. (1976). Six-Parameter Wave Spectra. In *15th Coastal Engineering Conference*, Vol. 1, pp. 301–328. Honolulu.

- [15] Hogben, N. and Cobb, F.C. (1986). Parametric Modelling of Directional Wave Spectra. In *Offshore Technology Conference*, Paper OTC 5212, Houston.
- [16] Holtrop, J. (1984). A Statistical Re-analysis of Resistance and Propulsion Data. *International Shipbuilding Progress*, **31**(363), 272–276.

# Symbols and Abbreviations

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$[A]$	ship added mass matrix
$A_{y-i}$	lateral profile area of hull section $i$
$A_w$	hull wetted surface area
$A(P_i)$	normalization factor for ten parameter spectral component $i$
$[B]$	ship damping matrix
$B_{max}$	ship maximum beam
$C_B$	hull block coefficient
$C_{Dx}$	hull resistance coefficient
$C_{Dy}$	hull cross-flow drag coefficient
$C_{eddy}^{hull}$	hull eddy coefficient
$C_W$	hull waterplane coefficient
$c_{root}$	root chord length
$c_{tip}$	tip chord length
$[D]$	influence matrix giving flow normal velocities from hull source strengths
$[E]$	influence matrix giving flow potentials from hull source strengths
$D_{prop}$	propeller diameter
$\{F^{cross}\}$	cross-flow drag vector
$F_4^{hull-eddy}$	hull eddy roll damping force
$\{F^{prop}\}$	propulsion force vector
$\{F^{resist}\}$	resistance force vector
$G(\nu)$	directional wave spectral spreading function
$g$	gravitational acceleration
$H_s$	significant wave height
$h_{s-i}$	significant wave height for spectral component $i$
$J_{prop}$	propeller advance coefficient
$K_T$	propeller thrust coefficient
$K_T^0, K_T^J, K_T^{JJ}$	propeller thrust quadratic coefficients
$\overline{KG}$	vertical centre of gravity relative to baseline
$k_{\delta j}^D$	rudder autopilot derivative gain for motion mode $j$
$k_{\delta j}^I$	rudder autopilot integral gain for motion mode $j$
$k_{\delta j}^P$	rudder autopilot proportional gain for motion mode $j$
$L$	ship length between perpendiculars



$M_i(\nu)$	directional spreading function for ten parameter spectrum component $i$
$P_i$	directional spreading parameter for ten parameter spectrum component $i$
$N'_r$	linear yaw-yaw maneuvering force coefficient
$N'_{r r }$	yaw velocity dependent nonlinear yaw-yaw maneuvering force coefficient
$N'_{rv^2}$	sway velocity dependent nonlinear yaw-yaw maneuvering force coefficient
$N_{seg}$	number of hull longitudinal sections
$N'_v$	linear yaw-sway maneuvering force coefficient
$N'_{vr^2}$	yaw velocity dependent nonlinear yaw-sway maneuvering force coefficient
$n_j$	normal component $j$ for vector pointing into ship
$n_{prop}$	propeller speed in revolutions per second
$P_i$	directional spreading parameter for ten parameter spectrum component $i$
$RPM^{prop}$	propeller RPM
$\dot{RPM}^{prop}$	time derivative of propeller RPM
$\ddot{RPM}^{prop}$	second derivative with respect to time of propeller RPM
$RPM_C^{prop}$	command propeller RPM
$r_{xx}$	roll radius of gyration
$r_{yy}$	pitch radius of gyration
$r_{zz}$	yaw radius of gyration
$S_{hull}$	hull wetted surface
$S_{\omega_I}(\omega_I)$	point wave spectral density
$S_{\omega_I, \nu}(\omega_I, \nu)$	directional wave spectral density
$s$	foil span
$T_p$	peak wave period
$T_z$	zero-crossing period
$T_1$	average wave period
$t_{prop}$	propeller thrust deduction coefficient
$U$	ship forward speed
$v^{cross}$	cross-flow velocity
$w_{prop}$	propeller wake fraction
$x, y, z$	coordinates in translating earth axes

$Y'_r$	linear sway-yaw maneuvering force coefficient
$Y'_{v r }$	yaw velocity dependent nonlinear sway-yaw maneuvering force coefficient
$Y'_v$	linear sway-sway maneuvering force coefficient
$Y'_{v r }$	yaw velocity dependent nonlinear sway-sway maneuvering force coefficient
$Y'_{v v }$	sway velocity dependent nonlinear sway-sway maneuvering force coefficient
$\alpha^*$	normalization term for JONSWAP spectrum
$\beta_s$	sea direction relative to ship
$\gamma$	spectral peak parameter
$\Delta\tau$	retardation function time interval
$\delta^{rudder}$	rudder deflection angle
$\dot{\delta}^{rudder}$	rudder velocity
$\ddot{\delta}^{rudder}$	rudder acceleration
$\delta_C^{rudder}$	command rudder angle
$\zeta_{RPM}$	propeller RPM response damping
$\zeta_\delta$	rudder nondimensional damping response constant
$\eta_j$	ship motion displacement for mode $j$ in translating earth coordinate system
$\eta_j^f$	ship motion displacement for mode $j$ in earth-fixed coordinate system
$\dot{\eta}_j$	ship motion velocity for mode $j$ in translating earth coordinate system
$\theta_s$	spreading angle for cosine squared spectral spreading
$\kappa$	JONSWAP spectrum exponent
$\lambda_i$	spectral shape parameter for spectral component $i$
$\nu$	wave direction (from) in earth-fixed axes
$\bar{\nu}$	mean wave direction (from) in earth-fixed axes
$\bar{\nu}_i$	mean wave direction (from) for spectral component $i$
$\rho$	water density
$\{\sigma\}$	vector of hull source strengths
$\tau_{max}$	maximum time for retardation function
$\{\phi\}$	vector of hull flow potentials
$\{\partial\phi/\partial n\}$	vector of flow normal velocities
$\chi$	ship heading (to) in earth-fixed axes
$\omega_e$	encounter frequency
$\omega_I$	incident wave frequency

$\omega_p$	peak wave frequency
$\omega_{p-i}$	peak wave frequency for spectral component $i$
$\omega_{RPM}$	propeller RPM response natural frequency
$\omega_\delta$	rudder response natural frequency
$\Delta$	displacement

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# Annex A: Files for Panelling the Hull with SM3DPanelHull

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## A.1 Format of Input Panel Hull File

### Record (a), Beginning Record

“begin SM3DPanelHull” (1 character string with 2 words)

### Record (b), Run Title

“label”, label (2 character strings)

“label” Record tag.

label Title for run. This can include spaces.

### Record (c), Run Type

“runOption”, runOption (2 character strings)

“runOption” Record tag.

runOption Option for run.

full - Full run including panelling of hull.

noPanel - No panelling of the hull. This run type can be used for checking of the patch hull.

### Record (d), Patch Hull File Name

“patchHullFileName”, patchHullFileName (2 character strings)

“patchHullFileName” Record tag.

patchHullFileName Name of file with description of patch hull.

### Record (e), Plot Output Option

This record is optional.

(“plotOutOption”, plotOutOption (2 character strings)

“plotOutOption” Record tag.

plotOutOption Option for making plots.

screenFile - Plots are both plotted on the screen and to a file.

screen - Plots are only plotted on the screen.

file - Plots are only written to a file (default).

### **Record (f), Beginning of Patch Hull Plot Data**

This record is optional.

“begin patchPlots” (1 character string with 2 words)

**Note:** If this record is entered, then it can be followed by an arbitrary number of repetitions of Records (f1) to (f5) giving plot parameters. Record (f6) must follow at the end of plot parameter data.

### **Record (f1), Patch Hull Plot Options**

This record is required if a plot is being specified.

“patchPlotOptions”, fileFormat, starboardOption (3 character strings)

“patchPlotOptions” Record tag.

fileFormat Plot format. Available formats are bmp, eps, gif, pdf, png, ppm, ps, svg, tiff, and wmf.

starboardOption Option for plotting starboard portion of hull.

noStarboard - Only port side of hull is plotted.

includeStarboard - Both starboard and port sides of hull are plotted.

### **Record (f2), Patch Hull Plot File Name**

This record is required if a plot is being specified.

“patchPlotFileName”, patchPlotFileName (2 character strings)

“patchPlotFileName” Record tag.

patchPlotFileName Name of output plot file.

### **Record (f3), Patch Hull View Point**

This record is required if a plot is being specified.

“patchViewPoint”, xView, yView, zBlView (1 character string, 3 floats)

“patchViewPoint” Record tag.

xView  $x$  coordinate of view point relative to the patch hull origin (typically midships).

yView  $y$  coordinate of view point relative to ship centreline.

zBlView  $z$  coordinate of view point relative to ship baseline

### **Record (f4), Zoom Factor**

This record is optional if a plot is being specified.

“patchZoomFactor”, zoomFactor (1 character string, 1 float)

“patchZoomFactor” Record tag.

patchZoomFactor Plot zoom factor. For a zoom factor of 1.0, the program attempts to fill the view area with the plot.

**Note:** If this record is omitted for a plot, then a default of 1.0 is used.

### **Record (f5), Patch Image Size**

This record is optional if a plot is being specified.

“patchImageSize”, widthmm, heightmm (1 character string, 2 floats)

“patchImageSize” Record tag.

widthmm Plot width (mm). (Default 150 mm)

heightmm Plot height (mm). (Default 100 mm)

**Note:** If this record is omitted for a plot, then the default values are used.

### **Record (f6), End of Plot Data**

This record is required if Record (f) has been entered.

“end patchPlots” (1 character string with 2 words)

### **Record (g), Wet Panel Hull File Name**

“wetPanelFileName”, wetPanelFileName (2 character strings)

“wetPanelFileName” Record tag.

wetPanelFileName Name of output file describing hull in Python pickle format.

### **Record (h), Dry Panel Hull Option**

“dryPanelOption”, dryPanelOption (2 character strings)

“dryPanelOption” Record tag.

dryPanelOption Option for panelling dry portion of hull.

dryPanel - Dry portion of hull is panelled.

noDryPanel - Dry portion of hull is not panelled.

**Note:** If the option dryPanel is selected, then the input patch hull should describe a fully enclosed volume.

### **Record (h1), Dry Panel Hull File Name**

This record is only required if dryPanelOption is set to dryPanel in Record (h).

“dryPanelFileName”, dryPanelFileName (2 character strings)

“dryPanelFileName” Record tag.

dryPanelFileName Name of output file describing hull in Python pickle format.

### **Record (i), Water Density**

“waterDensity”, waterDensity (1 character string, 1 float)

“waterDensity” Record tag.

waterDensity Water density (kg/m<sup>3</sup>). For salt water, a value of 1025 kg/m<sup>3</sup> is recommended. For fresh water, a value of 1000 kg/m<sup>3</sup> is recommended.

### **Record (j), Draft and Trim**

One of this record or Record (k) is required.

“draftTrim”, draftBlMid, trimBlStern (1 character string, 2 floats)

“draftTrim” Record tag.

draftBlMid Draft of baseline at midships (m).

trimBlStern Trim of baseline by stern (m).

### **Record (k), Displacement and LCG Location**

One of this record or Record (j) is required.

“dispLCG”, dispTonnesInput, lcgAftFpInput, draftBlMidGuess, trimBlSternGuess, tolDispTonnes, tolLcg (1 character string, 6 floats)

“dispLCG” Record tag.

dispTonnesInput Displacement (tonnes).

lcgAftFpInput Distance of LCG aft of fore perpendicular (m).

draftBlMidGuess Guess for draft of baseline at midships (m).

trimBlSternGuess Guess for trim of baseline by stern (m).

tolDispTonnes Non-dimensional tolerance on displacement. A value of 10<sup>-6</sup> is recommended.

tolLcg Non-dimensional tolerance on distance of LCG aft of fore perpendicular (m). A value of 10<sup>-6</sup> is recommended.



### **Record (l), Height of Centre of Gravity Above Baseline**

“shipKG”, shipKG (1 character string, 1 float)

“shipKG” Record tag.

shipKG Height of centre of gravity above baseline (m).

### **Record (m), Hull Surface Spline Interpolation Option**

“splineInterpOption”, splineInterpOption (2 character strings)

“splineInterpOption” Record tag.

splineInterpOption Option for interpolation of hull surface points.

oneDimen - When interpolating hull surface points, B-spline interpolation is used along input hull lines, and linear interpolation is used between hull lines. This option is more robust but can be less accurate than two dimensional spline interpolation.

twoDimen - Hull surface patches are represented by two dimensional B-splines. This option can be more accurate but can have robustness problems for surfaces with pronounced changes of curvature.

### **Record (n), Hull Panel Parameters**

“panelParameters”, areaPanelLimit, aspectPanelLimit, deltaNormalPanelLimitDeg (1 character string, 3 floats)

“panelParameters” Record tag.

areaPanelLimit Limit on area for hull panels (m<sup>2</sup>).

aspectPanelLimit Limiting hull panel aspect ratio. A value of 4.0 is recommended.

deltaNormalPanelLimitDeg Limit on normal angle between adjacent panels. A value of 15° is recommended.

### **Record (o), Beginning of Panelled Hull Plot Data**

This record is optional.

“begin panelPlots” (1 character string with 2 words)

**Note:** If this record is entered, then it can be followed by an arbitrary number of repetitions of Records (o1) to (o7) giving plot parameters. Record (o8) must follow at the end of plot parameter data.

### **Record (o1), Plot Type**

This record is required if a plot is being specified.

(2 character strings)

“panelPlotType”	Record tag.
panelPlotType	Type of plot. wet - Wet hull only is plotted. dry - Dry hull only is plotted. dryPanelOption must be “dryPanel” in Record (h). wetDry - Wet and dry hulls are plotted together. dryPanelOption must be “dryPanel” in Record (h).

### **Record (o2), Panel Plot Options**

This record is required if a plot is being specified.

“panelPlotOptions”, fileFormat, colourTable, starboardOption, smoothShadeOption, (5 character strings)

“panelPlotOptions”	Record tag.
fileFormat	Plot format. Available formats are bmp, eps, gif, pdf, png, ppm, ps, svg, tiff, and wmf.
colourTable	Colour table. Available tables are small, vga, rain, spec, grey, rrain, rspec, rgrey, temp, partialGrey, wetWhiteDryGrey, white, redHullYellowAppendages, and hullAppendagesProp.
starboardOption	Option for plotting starboard portion of hull. noStarboard - Only port side of hull is plotted. includeStarboard - Both starboard and port sides of hull are plotted.
smoothShadeOption	Option for shading of hull panels. nonSmooth - Each panel has a constant colour based on the centroid location. smooth - Each panel can have colour variation within the panel.

### **Record (o3), Panel Plot File Name**

This record is required if a plot is being specified.

“panelPlotFileName”, panelPlotFileName (2 character strings)

“panelPlotFileName”	Record tag.
panelPlotFileName	Name of output plot file.

#### **Record (o4), Panel Hull View Point**

This record is required if a plot is being specified.

“panelViewPoint”, xView, yView, zWView (1 character string, 3 floats)

“panelViewPoint” Record tag.

xView  $x$  coordinate of view point relative to ship LCG.

yView  $y$  coordinate of view point relative to ship centreline.

zWView  $z$  coordinate of view point relative to calm waterline.

#### **Record (o5), Zoom Factor**

This record is optional if a plot is being specified.

“panelZoomFactor”, zoomFactor (1 character string, 1 float)

“panelZoomFactor” Record tag.

zoomFactor Plot zoom factor. For a zoom factor of 1.0, the program attempts to fill the view area with the plot.

**Note:** If this record is omitted for a plot, then a default of 1.0 is used.

#### **Record (o6), Panel Image Size**

This record is optional if a plot is being specified.

“panelImageSize”, widthmm, heightmm (1 character string, 2 floats)

“panelImageSize” Record tag.

widthmm Plot width (mm). (Default 150 mm)

heightmm Plot height (mm). (Default 100 mm)

**Note:** If this record is omitted for a plot, then the default values are used.

#### **Record (o7), Stations for Cropping Plot**

This record is optional if a plot is being specified.

“panelCropStations”, stationMinCrop, stationMaxCrop (1 character string, 2 floats)

“panelCropStations” Record tag.

stationMinCrop Minimum station for cropping plot.

stationMaxCrop Maximum station for cropping plot.

**Note:** If this record is omitted for a plot, then there is no cropping of the plot.

**Record (o8), End of Plot Data**

“end panelPlots” (1 character string with 2 words)

**Record (p), End of Input File for SM3DPanelHull**

“end SM3DPanelHull” (1 character string with 2 words)

## A.2 Format of Input Patch Hull File

### Record (a), Beginning Record

“begin patchHull” (1 character string with 2 words)

### Record (b), Run Title

“label”, title (2 character strings)

“label” Record tag.

label Label for patch hull. This can include spaces.

### Record (c), Length Data

“lengthData”, lpp, stationAP, x0AftFP (1 character string, 3 floats)

“lengthData” Record tag.

lpp Ship length between perpendiculars (m)

stationAP Station number of the aft perpendicular. This value is typically 20.0

x0AftFP Distance from fore perpendicular to origin for converting input stations to  $x$  coordinates. This parameter only influences plotting of the patch hull. A value of  $lpp/2.0$  is recommended.

### Record (d), Scaling Parameters for Offsets

This record is optional.

“scaleYZ”, yScale, zScale (1 character string, 2 floats)

“scaleYZ” Record tag.

yScale Scale factor for input  $y$  offsets. A default of 1.0 is used if this record is omitted.

zScale Scale factor for input  $z$  offsets. A default of 1.0 is used if this record is omitted.

### Record (e), Beginning of Data for Hull Patch

This record is followed by repeated series of Records (e1) to (e4e), finishing with Record (e5). These groups of records can be repeated to describe an arbitrary number of patches encompassing the ship hull.

“begin patch” (1 character string with 2 words)

### Record (e1), Patch Title

“label”, label (2 character strings)

“label” Record tag.

label Title for patch. This can include spaces.

### **Record (e2), Normal Ranges for Checking of Hull Panelling**

“normalRanges”, nxMinLimit, nxMaxLimit, nyMinLimit, nyMaxLimit, nzMinLimit, nzMaxLimit (1 character string, 6 floats)

“normalRanges” Record tag.

nxMinLimit Minimum  $x$  normal component for patch surface.

nxMaxLimit Maximum  $x$  normal component for patch surface.

nyMinLimit Minimum  $y$  normal component for patch surface.

nyMaxLimit Maximum  $y$  normal component for patch surface.

nzMinLimit Minimum  $z$  normal component for patch surface.

nzMaxLimit Maximum  $z$  normal component for patch surface.

**Note:** The input normal ranges are intended to be broad ranges used for checking that generated panels aren’t pointing in the wrong direction. Hull normals point outward from the hull.

### **Record (e3), Limit on Maximum Area for Panels on Patch**

This record is optional

“areaPanelLimit”, areaPanelLimit (1 character string, 1 float)

“areaPanelLimit” Record tag.

areaPanelLimit Limit of maximum panel area on patch. A default of  $10^{99}$  is used if this record is omitted. This record can be used for areas requiring a finer mesh size than the remainder of the hull, such as a bulbous bow with sharp curvature.

### **Record (e4), Beginning of Hull Line Data**

A patch is described by repeated series of Records (e4) to (e4e) representing hull lines. A patch must consist of at least 2 hull lines.

“begin hullLine” (1 character string with 2 words)

### **Record (e4a), Station for Hull Line Offsets**

Record (e4) must be followed by either Record (e4a) or Record (e4b). If Record (e4a) is used, then all offsets on a hull line must have the same station.

“station”, station (1 character string, 1 float)

“station” Record tag.

station Station number for all offsets on hull line. Station 0 is at the fore perpendicular.

#### **Record (e4b), Stations for Hull Line Offsets**

Record (e4) must be followed by either Record (e4a) or Record (e4b).

“stations”, stations (1 character string, nOffset floats)

“stations” Record tag.

stations Array of nOffset station numbers, where nOffset is the number of offsets on the hull line. Station 0 is at the fore perpendicular.

#### **Record (e4c), Y Offsets for Hull Line**

“yOffsets”, yOffsets (1 character string, nOffset floats)

“yOffsets” Record tag.

yOffsets Array of nOffset *y* offsets, where nOffset is the number of offsets on the hull line.

#### **Record (e4d), Z Offsets for Hull Line**

“zBIOffsets”, zBIOffsets (1 character string, nOffset floats)

“zBIOffsets” Record tag.

zBIOffsets Array of nOffset *z* offsets relative to the baseline, where nOffset is the number of offsets on the hull line.

**Note:** Records (e4c) and (e4d) (and Record (e4b) if used) must contain data for the same number of offsets.

#### **Record (e4e), End of Data for Hull Line**

“end hullLine” (1 character string with 2 words)

#### **Record (e5), End of Data for Patch**

“end patch” (1 character string with 2 words)

#### **Record (f), End of Data for Patch Hull**

“end patchHull” (1 character string with 2 words)

### A.3 Sample Input File for SM3DPanelHull

```
begin SM3DPanelHull
label Generic frigate
runOption full
patchHullFileName genFrigPatch.inp
plotOutOption screen
begin patchPlots
    patchPlotOptions png includeStarboard
    patchPlotFileName patchFrontLowerView.png
    patchViewPoint 120.0 120.0 -60.0
    patchZoomFactor 1.2
    patchImageSize 150.0 100.0
end patchPlots
wetPanelFileName genFrigWetPanelHull.pkl
dryPanelOption dryPanel
dryPanelFileName genFrigDryPanelHull.pkl
waterDensity 1025.0
draftTrim 4.2 0.0
shipKG 6.0
splineInterpOption twoDimen
panelParameters 1.5 3.0 15.0
begin panelPlots
    panelPlotType wetDry
        panelPlotOptions png rain includeStarboard nonSmooth
        panelPlotFileName wetDryFrontLowerView.png
        panelViewPoint 120.0 120.0 -60.0
        panelZoomFactor 1.5
        panelImageSize 150.0 100.0
    panelPlotType wetDry
        panelPlotOptions png rain includeStarboard nonSmooth
        panelPlotFileName wetDryBackView.png
        panelViewPoint -200.0 0.0 0.0
        panelZoomFactor 1.5
        panelImageSize 150.0 100.0
    panelPlotType wetDry
        panelPlotOptions png rain includeStarboard nonSmooth
        panelPlotFileName wetDryFrontView.png
        panelViewPoint 200.0 0.0 0.0
        panelZoomFactor 1.5
        panelImageSize 150.0 100.0
    panelPlotType wetDry
```



```
    panelPlotOptions png rain includeStarboard nonSmooth
    panelPlotFileName wetDrySideView.png
    panelViewPoint 0.0 500.0 0.0
    panelZoomFactor 1.0
    panelImageSize 150.0 100.0
  panelPlotType wetDry
    panelPlotOptions png rain includeStarboard nonSmooth
    panelPlotFileName wetDryBottomView.png
    panelViewPoint 0.0 0.0 -500.0
    panelZoomFactor 1.0
    panelImageSize 150.0 100.0
end panelPlots
end SM3DPanelHull
```

## A.4 Sample Patch Hull Input File for SM3DPanelHull

```

begin patchHull
label Generic frigate
lengthData 120.0 20.0 60.0
#####
begin patch
label Smooth hull from station -1 to 0
normalRanges -0.5 1.0 -0.05 1.0 -1.0 0.2
begin hullLine
    stations -1.0
    yOffsets 0.0
    zOffsets 12.2
end hullLine
begin hullLine
    station 0
    yOffsets    0.000  0.030  0.036  0.048  0.065  0.090  0.122  0.161 !
                0.208  0.262  0.324  0.394  0.471  0.558  0.654  0.760 !
                0.875  0.997  1.127  1.264  1.409  1.560  1.718  1.881 !
                2.049  2.300  2.512  2.725  2.751
    zOffsets    4.427  4.700  4.977  5.253  5.530  5.806  6.083  6.359 !
                6.636  6.912  7.189  7.465  7.742  8.018  8.295  8.571 !
                8.848  9.124  9.401  9.677  9.954 10.230 10.507 10.783 !
                11.060 11.462 11.793 12.125 12.166
end hullLine
end patch
#####
begin patch
label Smooth hull from FP to AP
normalRanges -0.5 1.0 -0.05 1.0 -1.0 0.2
begin hullLine
    station 0
    yOffsets    0.000  0.030  0.036  0.048  0.065  0.090  0.122  0.161 !
                0.208  0.262  0.324  0.394  0.471  0.558  0.654  0.760 !
                0.875  0.997  1.127  1.264  1.409  1.560  1.718  1.881 !
                2.049  2.300  2.512  2.725  2.751
    zOffsets    4.427  4.700  4.977  5.253  5.530  5.806  6.083  6.359 !
                6.636  6.912  7.189  7.465  7.742  8.018  8.295  8.571 !
                8.848  9.124  9.401  9.677  9.954 10.230 10.507 10.783 !
                11.060 11.462 11.793 12.125 12.166
end hullLine
begin hullLine
    station 1
    yOffsets    0.000  0.169  0.283  0.387  0.485  0.575  0.656  0.728 !
                0.795  0.862  0.929  0.998  1.066  1.135  1.205  1.275 !

```

```

        1.346  1.417  1.491  1.565  1.641  1.719  1.799  1.884 !
        1.972  2.065  2.163  2.265  2.371  4.849
    zOffsets  0.000  0.000  0.276  0.553  0.829  1.106  1.382  1.659 !
        1.935  2.212  2.488  2.765  3.041  3.318  3.594  3.871 !
        4.147  4.424  4.700  4.977  5.253  5.530  5.806  6.083 !
        6.359  6.636  6.912  7.189  7.465 11.889
    end hullLine
    begin hullLine
        station 2
        yOffsets  0.000  0.169  0.449  0.693  0.902  1.085  1.250  1.404 !
        1.547  1.683  1.816  1.944  2.069  2.189  2.304  2.415 !
        2.523  2.630  2.736  2.840  2.944  3.048  3.153  3.260 !
        3.368  3.478  3.591  3.707  3.827  5.942
    zOffsets  0.000  0.000  0.276  0.553  0.829  1.106  1.382  1.659 !
        1.935  2.212  2.488  2.765  3.041  3.318  3.594  3.871 !
        4.147  4.424  4.700  4.977  5.253  5.530  5.806  6.083 !
        6.359  6.636  6.912  7.189  7.465 11.613
    end hullLine
    begin hullLine
        station 3
        yOffsets  0.000  0.169  0.684  1.073  1.394  1.662  1.896  2.111 !
        2.312  2.503  2.685  2.861  3.029  3.191  3.345  3.492 !
        3.632  3.767  3.895  4.019  4.139  4.254  4.367  4.477 !
        4.585  4.692  4.796  4.900  5.004  6.504
    zOffsets  0.000  0.000  0.276  0.553  0.829  1.106  1.382  1.659 !
        1.935  2.212  2.488  2.765  3.041  3.318  3.594  3.871 !
        4.147  4.424  4.700  4.977  5.253  5.530  5.806  6.083 !
        6.359  6.636  6.912  7.189  7.465 11.336
    end hullLine
    begin hullLine
        station 4
        yOffsets  0.000  0.169  1.095  1.637  2.035  2.367  2.653  2.908 !
        3.142  3.361  3.567  3.762  3.950  4.130  4.302  4.464 !
        4.618  4.760  4.893  5.017  5.132  5.240  5.341  5.435 !
        5.523  5.607  5.688  5.767  5.845  6.878
    zOffsets  0.000  0.000  0.276  0.553  0.829  1.106  1.382  1.659 !
        1.935  2.212  2.488  2.765  3.041  3.318  3.594  3.871 !
        4.147  4.424  4.700  4.977  5.253  5.530  5.806  6.083 !
        6.359  6.636  6.912  7.189  7.465 11.060
    end hullLine
    begin hullLine
        station 5
        yOffsets  0.000  0.169  1.341  2.094  2.620  3.032  3.376  3.675 !
        3.940  4.180  4.399  4.601  4.788  4.962  5.123  5.272 !
        5.410  5.537  5.653  5.759  5.857  5.945  6.027  6.101 !

```

```

        6.171  6.236  6.298  6.357  6.415  7.113
    zOffsets  0.000  0.000  0.276  0.553  0.829  1.106  1.382  1.659 !
              1.935  2.212  2.488  2.765  3.041  3.318  3.594  3.871 !
              4.147  4.424  4.700  4.977  5.253  5.530  5.806  6.083 !
              6.359  6.636  6.912  7.189  7.465 10.783
end hullLine
begin hullLine
station 6
    yOffsets  0.000  0.169  1.428  2.435  3.134  3.655  4.061  4.393 !
              4.675  4.921  5.137  5.329  5.502  5.658  5.800  5.928 !
              6.045  6.151  6.247  6.334  6.412  6.483  6.545  6.601 !
              6.652  6.699  6.744  6.788  6.831  7.301
    zOffsets  0.000  0.000  0.276  0.553  0.829  1.106  1.382  1.659 !
              1.935  2.212  2.488  2.765  3.041  3.318  3.594  3.871 !
              4.147  4.424  4.700  4.977  5.253  5.530  5.806  6.083 !
              6.359  6.636  6.912  7.189  7.465 10.507
end hullLine
begin hullLine
station 7
    yOffsets  0.000  0.169  1.428  2.646  3.555  4.188  4.658  5.023 !
              5.320  5.565  5.772  5.948  6.098  6.228  6.339  6.436 !
              6.520  6.595  6.661  6.721  6.776  6.826  6.872  6.913 !
              6.950  6.984  7.017  7.050  7.082  7.411
    zOffsets  0.000  0.000  0.276  0.553  0.829  1.106  1.382  1.659 !
              1.935  2.212  2.488  2.765  3.041  3.318  3.594  3.871 !
              4.147  4.424  4.700  4.977  5.253  5.530  5.806  6.083 !
              6.359  6.636  6.912  7.189  7.465 10.230
end hullLine
begin hullLine
station 8
    yOffsets  0.000  0.169  1.428  2.687  3.813  4.587  5.120  5.504 !
              5.799  6.033  6.222  6.376  6.503  6.607  6.692  6.762 !
              6.820  6.870  6.913  6.951  6.987  7.020  7.052  7.083 !
              7.114  7.145  7.175  7.204  7.231  7.478
    zOffsets  0.000  0.000  0.276  0.553  0.829  1.106  1.382  1.659 !
              1.935  2.212  2.488  2.765  3.041  3.318  3.594  3.871 !
              4.147  4.424  4.700  4.977  5.253  5.530  5.806  6.083 !
              6.359  6.636  6.912  7.189  7.465  9.954
end hullLine
begin hullLine
station 9
    yOffsets  0.000  0.169  1.428  2.687  3.915  4.792  5.416  5.826 !
              6.120  6.341  6.511  6.644  6.749  6.831  6.895  6.946 !
              6.986  7.021  7.051  7.080  7.108  7.135  7.162  7.188 !
              7.214  7.239  7.265  7.291  7.316  7.521

```

```

        zOffsets  0.000  0.000  0.276  0.553  0.829  1.106  1.382  1.659 !
                  1.935  2.212  2.488  2.765  3.041  3.318  3.594  3.871 !
                  4.147  4.424  4.700  4.977  5.253  5.530  5.806  6.083 !
                  6.359  6.636  6.912  7.189  7.465  9.677
end hullLine
begin hullLine
station 10
    yOffsets  0.000  0.169  1.428  2.687  3.947  4.963  5.568  5.972 !
              6.262  6.475  6.635  6.758  6.853  6.926  6.981  7.021 !
              7.048  7.072  7.096  7.120  7.144  7.169  7.193  7.217 !
              7.241  7.265  7.290  7.314  7.338  7.507
    zOffsets  0.000  0.000  0.276  0.553  0.829  1.106  1.382  1.659 !
              1.935  2.212  2.488  2.765  3.041  3.318  3.594  3.871 !
              4.147  4.424  4.700  4.977  5.253  5.530  5.806  6.083 !
              6.359  6.636  6.912  7.189  7.465  9.401
end hullLine
begin hullLine
station 11
    yOffsets  0.000  0.169  1.428  2.687  3.956  4.930  5.513  5.913 !
              6.207  6.429  6.598  6.729  6.829  6.905  6.960  7.001 !
              7.033  7.060  7.086  7.115  7.144  7.168  7.193  7.217 !
              7.241  7.265  7.290  7.314  7.338  7.507
    zOffsets  0.000  0.000  0.276  0.553  0.829  1.106  1.382  1.659 !
              1.935  2.212  2.488  2.765  3.041  3.318  3.594  3.871 !
              4.147  4.424  4.700  4.977  5.253  5.530  5.806  6.083 !
              6.359  6.636  6.912  7.189  7.465  9.401
end hullLine
begin hullLine
station 12
    yOffsets  0.000  0.169  1.428  2.677  3.833  4.758  5.372  5.797 !
              6.107  6.340  6.519  6.656  6.761  6.842  6.905  6.954 !
              6.994  7.028  7.058  7.087  7.116  7.143  7.170  7.198 !
              7.229  7.259  7.288  7.314  7.338  7.507
    zOffsets  0.000  0.000  0.276  0.553  0.829  1.106  1.382  1.659 !
              1.935  2.212  2.488  2.765  3.041  3.318  3.594  3.871 !
              4.147  4.424  4.700  4.977  5.253  5.530  5.806  6.083 !
              6.359  6.636  6.912  7.189  7.465  9.401
end hullLine
begin hullLine
station 13
    yOffsets  0.000  0.169  1.383  2.554  3.624  4.500  5.129  5.582 !
              5.920  6.177  6.376  6.532  6.652  6.746  6.820  6.878 !
              6.923  6.960  6.993  7.024  7.056  7.086  7.115  7.143 !
              7.169  7.193  7.218  7.242  7.266  7.437
    zOffsets  0.000  0.000  0.276  0.553  0.829  1.106  1.382  1.659 !

```

```

        1.935  2.212  2.488  2.765  3.041  3.318  3.594  3.871 !
        4.147  4.424  4.700  4.977  5.253  5.530  5.806  6.083 !
        6.359  6.636  6.912  7.189  7.465  9.401
end hullLine
begin hullLine
station 14
    yOffsets  0.000  0.169  1.314  2.364  3.311  4.126  4.745  5.228 !
               5.605  5.903  6.139  6.326  6.472  6.587  6.677  6.748 !
               6.803  6.849  6.888  6.924  6.957  6.988  7.015  7.041 !
               7.066  7.092  7.117  7.142  7.168  7.345
    zOffsets  0.000  0.000  0.276  0.553  0.829  1.106  1.382  1.659 !
               1.935  2.212  2.488  2.765  3.041  3.318  3.594  3.871 !
               4.147  4.424  4.700  4.977  5.253  5.530  5.806  6.083 !
               6.359  6.636  6.912  7.189  7.465  9.401
end hullLine
begin hullLine
station 15
    yOffsets  0.000  0.169  0.899  1.804  2.682  3.503  4.186  4.721 !
               5.147  5.494  5.776  6.005  6.189  6.337  6.456  6.551 !
               6.628  6.690  6.742  6.784  6.819  6.849  6.876  6.902 !
               6.928  6.954  6.980  7.006  7.032  7.214
    zOffsets  0.000  0.000  0.276  0.553  0.829  1.106  1.382  1.659 !
               1.935  2.212  2.488  2.765  3.041  3.318  3.594  3.871 !
               4.147  4.424  4.700  4.977  5.253  5.530  5.806  6.083 !
               6.359  6.636  6.912  7.189  7.465  9.401
end hullLine
begin hullLine
station 16
    yOffsets  0.000  0.169  0.632  1.501  2.359  3.180  3.892  4.473 !
               4.931  5.295  5.588  5.827  6.021  6.177  6.301  6.400 !
               6.478  6.540  6.591  6.631  6.663  6.690  6.718  6.745 !
               6.773  6.800  6.828  6.856  7.049
    zOffsets  0.276  0.276  0.553  0.829  1.106  1.382  1.659  1.935 !
               2.212  2.488  2.765  3.041  3.318  3.594  3.871  4.147 !
               4.424  4.700  4.977  5.253  5.530  5.806  6.083  6.359 !
               6.636  6.912  7.189  7.465  9.401
end hullLine
begin hullLine
station 17
    yOffsets  0.000  0.169  0.793  1.949  2.939  3.804  4.465  4.955 !
               5.322  5.603  5.819  5.988  6.122  6.229  6.313  6.379 !
               6.430  6.472  6.505  6.534  6.564  6.593  6.622  6.651 !
               6.680  6.884
    zOffsets  1.106  1.106  1.382  1.659  1.935  2.212  2.488  2.765 !
               3.041  3.318  3.594  3.871  4.147  4.424  4.700  4.977 !

```

```

        5.253  5.530  5.806  6.083  6.359  6.636  6.912  7.189 !
        7.465  9.401
end hullLine
begin hullLine
station 18
    yOffsets  0.000  0.169  2.575  3.945  4.684  5.173  5.521  5.771 !
               5.949  6.073  6.153  6.206  6.246  6.280  6.313  6.346 !
               6.379  6.412  6.446  6.479  6.512  6.545  6.578  6.611 !
               6.645  6.678  6.711
    zOffsets  2.499  2.499  2.765  3.041  3.318  3.594  3.871  4.147 !
               4.424  4.700  4.977  5.253  5.530  5.806  6.083  6.359 !
               6.636  6.912  7.189  7.465  7.742  8.018  8.295  8.571 !
               8.848  9.124  9.401
end hullLine
begin hullLine
station 19
    yOffsets  0.000  0.406  4.924  5.410  5.643  5.775  5.846  5.890 !
               5.931  5.972  6.013  6.055  6.096  6.137  6.178  6.219 !
               6.260  6.302  6.343  6.384  6.425  6.466  6.507
    zOffsets  3.611  3.611  3.871  4.147  4.424  4.700  4.977  5.253 !
               5.530  5.806  6.083  6.359  6.636  6.912  7.189  7.465 !
               7.742  8.018  8.295  8.571  8.848  9.124  9.401
end hullLine
begin hullLine
station 20
    yOffsets  0.000  2.0    4.194  5.041  5.300  5.413  5.473  5.530 !
               5.586  5.640  5.692  5.744  5.795  5.846  5.896  5.947 !
               5.998  6.049  6.101  6.151  6.201  6.251  6.302
    zOffsets  3.870  3.870  3.871  4.147  4.424  4.700  4.977  5.253 !
               5.530  5.806  6.083  6.359  6.636  6.912  7.189  7.465 !
               7.742  8.018  8.295  8.571  8.848  9.124  9.401
end hullLine
end patch
#####
begin patch
label Outer transom
normalRanges -1.0 0.9 -0.1 0.1 -0.1 0.1
areaPanelLimit 0.2
begin hullLine
    station 20
    yOffsets 6.302
    zOffsets 9.401
end hullLine
begin hullLine
    station 20

```

```

        yOffsets 6.251 6.251
        zOffsets 9.124 9.401
    end hullLine
begin hullLine
    station 20
    yOffsets 5.998 5.998
    zOffsets 7.742 9.401
end hullLine
begin hullLine
    station 20
    yOffsets 5.473 5.473
    zOffsets 4.977 9.401
end hullLine
begin hullLine
    station 20
    yOffsets 5.041 5.041
    zOffsets 4.147 9.401
end hullLine
begin hullLine
    station 20
    yOffsets 4.194 4.194
    zOffsets 3.871 9.401
end hullLine
end patch
#####
begin patch
label Inner transom
normalRanges -1.0 0.9 -0.1 0.1 -0.1 0.1
areaPanelLimit 0.2
begin hullLine
    station 20
    yOffsets 4.194 4.194
    zOffsets 3.871 9.401
end hullLine
begin hullLine
    station 20
    yOffsets 2.000 2.000
    zOffsets 3.870 9.401
end hullLine
begin hullLine
    station 20
    yOffsets 0.000 0.000
    zOffsets 3.870 9.401
end hullLine
end patch

```



```
#####
begin patch
label Deck
normalRanges -0.1 0.1 -0.1 0.1 0.9 1.0
begin hullLine
    station -1
    yOffsets 0
    zOffsets 12.2
end hullLine
begin hullLine
    station 0
    yOffsets 2.751 0
    zOffsets 12.166 12.166
end hullLine
begin hullLine
    station 1
    yOffsets 4.849 0
    zOffsets 11.889 11.889
end hullLine
begin hullLine
    station 2
    yOffsets 5.942 0
    zOffsets 11.613 11.613
end hullLine
begin hullLine
    station 3
    yOffsets 6.504 0
    zOffsets 11.336 11.336
end hullLine
begin hullLine
    station 4
    yOffsets 6.878 0
    zOffsets 11.060 11.060
end hullLine
begin hullLine
    station 5
    yOffsets 7.113 0
    zOffsets 10.783 10.783
end hullLine
begin hullLine
    station 6
    yOffsets 7.301 0
    zOffsets 10.507 10.507
end hullLine
begin hullLine
```

```

        station 7
        yOffsets 7.411 0
        zOffsets 10.230 10.230
end hullLine
begin hullLine
    station 8
    yOffsets 7.478 0
    zOffsets 9.954 9.954
end hullLine
begin hullLine
    station 9
    yOffsets 7.521 0
    zOffsets 9.677 9.677
end hullLine
begin hullLine
    station 10
    yOffsets 7.507 0
    zOffsets 9.401 9.401
end hullLine
begin hullLine
    station 11
    yOffsets 7.507 0
    zOffsets 9.401 9.401
end hullLine
begin hullLine
    station 12
    yOffsets 7.507 0
    zOffsets 9.401 9.401
end hullLine
begin hullLine
    station 13
    yOffsets 7.437 0
    zOffsets 9.401 9.401
end hullLine
begin hullLine
    station 14
    yOffsets 7.345 0
    zOffsets 9.401 9.401
end hullLine
begin hullLine
    station 15
    yOffsets 7.214 0
    zOffsets 9.401 9.401
end hullLine
begin hullLine

```

```

        station 16
        yOffsets 7.049 0
        zOffsets 9.401 9.401
    end hullLine
    begin hullLine
        station 17
        yOffsets 6.884 0
        zOffsets 9.401 9.401
    end hullLine
    begin hullLine
        station 18
        yOffsets 6.711 0
        zOffsets 9.401 9.401
    end hullLine
    begin hullLine
        station 19
        yOffsets 6.507 0
        zOffsets 9.401 9.401
    end hullLine
    begin hullLine
        station 20
        yOffsets 6.302 0
        zOffsets 9.401 9.401
    end hullLine
end patch
end patchHull

```

## A.5 Sample Output File for SM3DPanelHull

Program SM3DPanelHull

ShipMo3D library Version 1.0c - 26 November 2007

Time : Wed Feb 06 13:20:07 2008

Run title:

Generic frigate

\*\*\*\* ECHO OF USER INPUT \*\*\*\*

Input patch hull file name:

genFrigPatch.inp

Plot output option : screen

Patch plot parameters

File format : png

Starboard option : includeStarboard

Plot file name : patchFrontLowerView.png

View point location : 120.000 120.000 -60.000

Zoom factor : 1.200 (input)

Image width and height (mm) : 150.0 100.0 (input)

Wet panel file name:

genFrigWetPanelHull.pkl

Dry panel option : dryPanel

Dry panel file name:

genFrigDryPanelHull.pkl

Water density : 1025.000 kg/m3

Ship loading condition

Draft of baseline at midships : 4.200 m

Trim of baseline by stern : 0.000 m

Height of CG above baseline : 6.000 m

Hull spline interpolation option : twoDimen

Hull panelling parameters

Limit on hull panel area : 1.500000 m2

Limit on aspect ratio : 3.000000

Limit normal angles between panels : 15.0 deg

Panel plot parameters

Plot type : wetDry  
File format : png  
Colour table : rain  
Starboard option : includeStarboard  
Smooth shade option : nonSmooth  
Plot file name : wetDryFrontLowerView.png  
View point location : 120.000 120.000 -60.000  
Zoom factor : 1.500 (input)  
Image width and height (mm) : 150.0 100.0 (input)  
No cropping of image

Panel plot parameters

Plot type : wetDry  
File format : png  
Colour table : rain  
Starboard option : includeStarboard  
Smooth shade option : nonSmooth  
Plot file name : wetDryBackView.png  
View point location : -200.000 0.000 0.000  
Zoom factor : 1.500 (input)  
Image width and height (mm) : 150.0 100.0 (input)  
No cropping of image

Panel plot parameters

Plot type : wetDry  
File format : png  
Colour table : rain  
Starboard option : includeStarboard  
Smooth shade option : nonSmooth  
Plot file name : wetDryFrontView.png  
View point location : 200.000 0.000 0.000  
Zoom factor : 1.500 (input)  
Image width and height (mm) : 150.0 100.0 (input)  
No cropping of image

Panel plot parameters

Plot type : wetDry  
File format : png  
Colour table : rain  
Starboard option : includeStarboard

Smooth shade option : nonSmooth  
 Plot file name : wetDrySideView.png  
 View point location : 0.000 500.000 0.000  
 Zoom factor : 1.000 (input)  
 Image width and height (mm) : 150.0 100.0 (input)  
 No cropping of image

#### Panel plot parameters

Plot type : wetDry  
 File format : png  
 Colour table : rain  
 Starboard option : includeStarboard  
 Smooth shade option : nonSmooth  
 Plot file name : wetDryBottomView.png  
 View point location : 0.000 0.000 -500.000  
 Zoom factor : 1.000 (input)  
 Image width and height (mm) : 150.0 100.0 (input)  
 No cropping of image

#### \*\*\*\* PATCH PROPERTIES FOR WET HULL \*\*\*\*

#### Summary of patch panels

Patch label : Smooth hull from FP to AP (wet)  
 Number of panels : 610 (port side of hull)  
 Total panel area : 875.515 m2  
 Average panel area : 1.435 m2  
 Minimum panel area : 0.192 m2  
 Maximum panel area : 1.806 m2

Normal ranges (minimum and maximum)

	Actual	User input limits
nx	-0.238 0.417	-0.500 1.000
ny	-0.048 0.990	-0.050 1.000
nz	-1.000 -0.097	-1.000 0.200

Patch label : Outer transom (wet)  
 Number of panels : 2 (port side of hull)  
 Total panel area : 0.197849 m2  
 Average panel area : 0.098925 m2  
 Minimum panel area : 0.058849 m2  
 Maximum panel area : 0.139000 m2

Normal ranges (minimum and maximum)

	Actual	User input limits	
nx	-1.000 -1.000	-1.000	0.900
ny	-0.000 0.000	-0.100	0.100
nz	-0.000 -0.000	-0.100	0.100

Patch label : Inner transom (wet)  
 Number of panels : 12 (port side of hull)  
 Total panel area : 1.383222 m2  
 Average panel area : 0.115269 m2  
 Minimum panel area : 0.115061 m2  
 Maximum panel area : 0.115368 m2

Normal ranges (minimum and maximum)

	Actual	User input limits	
nx	-1.000 -1.000	-1.000	0.900
ny	-0.000 0.000	-0.100	0.100
nz	-0.000 0.000	-0.100	0.100

Panel area properties for all patches (port side of hull only)  
 Total surface area 877.096  
 Sum area\*nx -0.002  
 Sum area\*ny 438.097  
 Sum area\*nz -672.273

\*\*\*\* PROPERTIES FOR PANELLED WET HULL \*\*\*\*

Summary of hydrostatic properties

Number of panels on port side	:	624
Length between perpendiculars	:	120.000 m
Draft of baseline at midships	:	4.200 m
Trim of baseline by stern	:	0.000 m
Beam based on maximum y value	:	14.115 m
Volume	:	3625.687 m3
Water density	:	1025.000 kg/m3
Mass	:	3716329.367494 kg
LCB of aft of FP (m)	:	61.739 m
X origin aft of FP (m)	:	61.739 m
X value of LCB	:	0.000 m
Center of buoyancy wrt waterline	:	-1.620 m
Wetted surface area	:	1754.193 m2
Waterplane area	:	1344.547 m2
X value of center of floatation	:	-5.016 m
Integral of waterplane area*X**2	:	1235150.552 m4

Integral of waterplane area\*Y\*\*2 : 17543.034 m4  
 KG, height of CG above baseline : 6.000 m  
 Height of CG above waterline : 1.800 m  
 Metacentric height from hydrostatics : 1.418 m

Calculated properties for checking of mesh

Closure error sum of area\*nx : -0.003063 m2  
 Closure error/approx front area : -0.000066  
 Profile area : 438.097247 m2  
 Volumes based on integration over hull surface  
 Integral of x\*nx : 3625.983362 m3  
 Integral of y\*ny : 3625.746556 m3  
 Integral of z\*nz : 3625.687188 m3  
 XCB based on integration over hull surface  
 From integral of 0.5\*x\*x\*nx : 0.001671 m  
 From integral of x\*y\*ny : 0.005264 m  
 From integral of x\*z\*nz : 0.000000 m  
 ZCB based on integration over hull surface  
 Based on integral of z\*x\*nx : -1.623399 m  
 Based on integral of z\*y\*ny : -1.626946 m  
 Based on integral of 0.5\*z\*z\*nz : -1.620452 m

\*\*\*\* PATCH PROPERTIES FOR DRY HULL \*\*\*\*

Summary of patch panels

Patch label : Smooth hull from station -1 to 0 (dry)  
 Number of panels : 20 (port side of hull)  
 Total panel area : 26.222 m2  
 Average panel area : 1.311 m2  
 Minimum panel area : 0.252 m2  
 Maximum panel area : 2.423 m2

Normal ranges (minimum and maximum)  

	Actual		User input limits	
nx	0.114	0.366	-0.500	1.000
ny	0.791	0.990	-0.050	1.000
nz	-0.490	-0.088	-1.000	0.200

Patch label : Smooth hull from FP to AP (dry)  
 Number of panels : 4 (port side of hull)  
 Total panel area : 1.509090 m2  
 Average panel area : 0.377273 m2



Minimum panel area : 0.302008 m2

Maximum panel area : 0.423730 m2

Normal ranges (minimum and maximum)

	Actual	User input limits
nx	0.201 0.380	-0.500 1.000
ny	0.791 0.976	-0.050 1.000
nz	-0.492 -0.089	-1.000 0.200

Patch label : Smooth hull from FP to AP (dry)

Number of panels : 496 (port side of hull)

Total panel area : 733.646 m2

Average panel area : 1.479 m2

Minimum panel area : 1.263 m2

Maximum panel area : 2.083 m2

Normal ranges (minimum and maximum)

	Actual	User input limits
nx	-0.059 0.335	-0.500 1.000
ny	0.767 0.997	-0.050 1.000
nz	-0.575 -0.079	-1.000 0.200

Patch label : Outer transom (dry)

Number of panels : 30 (port side of hull)

Total panel area : 5.371186 m2

Average panel area : 0.179040 m2

Minimum panel area : 0.018529 m2

Maximum panel area : 0.447905 m2

Normal ranges (minimum and maximum)

	Actual	User input limits
nx	-1.000 -1.000	-1.000 0.900
ny	-0.000 0.000	-0.100 0.100
nz	-0.000 0.000	-0.100 0.100

Patch label : Outer transom (dry)

Number of panels : 16 (port side of hull)

Total panel area : 3.076660 m2

Average panel area : 0.192291 m2

Minimum panel area : 0.109363 m2

Maximum panel area : 0.282395 m2

Normal ranges (minimum and maximum)

	Actual	User input limits
nx	-1.000 -1.000	-1.000 0.900
ny	-0.000 0.000	-0.100 0.100

nz -0.000 0.000 -0.100 0.100

Patch label : Inner transom (dry)  
Number of panels : 110 (port side of hull)  
Total panel area : 21.812994 m2  
Average panel area : 0.198300 m2  
Minimum panel area : 0.198300 m2  
Maximum panel area : 0.198300 m2

Normal ranges (minimum and maximum)

	Actual	User input limits
nx	-1.000 -1.000	-1.000 0.900
ny	-0.000 0.000	-0.100 0.100
nz	-0.000 0.000	-0.100 0.100

Patch label : Deck (dry)  
Number of panels : 585 (port side of hull)  
Total panel area : 833.177 m2  
Average panel area : 1.424 m2  
Minimum panel area : 0.092 m2  
Maximum panel area : 1.626 m2

Normal ranges (minimum and maximum)

	Actual	User input limits
nx	-0.054 0.019	-0.100 0.100
ny	-0.005 0.003	-0.100 0.100
nz	0.999 1.000	0.900 1.000

Panel area properties for all patches (port side of hull only)

Total surface area 1624.815

Sum area\*nx 0.006

Sum area\*ny 730.136

Sum area\*nz 672.377

\*\*\*\* PROPERTIES FOR PANELLED DRY HULL \*\*\*\*

Calculated properties for checking of mesh

Closure error sum of area\*nx : 0.011719 m2

Closure error/approx front area : 0.000103

Profile area : 730.136047 m2

Volumes based on integration over dry hull surface

Integral of x\*nx : 8626.923753 m3

Integral of y\*ny : 8613.883638 m3

Integral of z\*nz : 8616.112824 m3

X center of volume based on integration over dry hull surface

From integral of  $0.5*x*x*n_x$  : 1.154566 m

From integral of  $x*y*n_y$  : 1.155592 m

From integral of  $x*z*n_z$  : 1.167543 m

ZCB based on integration over hull surface

Based on integral of  $z*x*n_x$  : 3.043504 m

Based on integral of  $z*y*n_y$  : 3.046249 m

Based on integral of  $0.5*z*z*n_z$  : 3.050093 m

\*\*\*\* CHECK OF CLOSURE FOR COMBINED WET AND DRY HULL \*\*\*\*

Calculated properties for checking combined mesh of wet and dry hull

Closure error sum of  $area*n_x$  : 0.008656 m<sup>2</sup>

Closure error/approx front area : 0.000054

Closure error sum of  $area*n_z$  : 0.206271 m<sup>2</sup>

Closure error/approx top area : 0.000005

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# **Annex B: Files for Radiation and Diffraction Computations with SM3DRadDif**

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## **B.1 Format of Input Radiation and Diffraction File for SM3DRadDif**

### **Record (a), Beginning Record**

“begin SM3DRadDif”(1 character string with 2 words)

### **Record (b), Run Label**

“label”, label (2 character strings)

“label”    Record tag.

label      Label for run. This can include spaces.

### **Record (c), Wet Panel Hull File Name**

“wetPanelFileName”, wetPanelFileName (2 character strings)

“wetPanelFileName”    Record tag.

wetPanelFileName      Name of file describing hull produced by SM3DPanelHull.  
This file is in Python pickle format.

### **Record (d), Radiation and Diffraction Database File Name**

“radDifDBFileName”, radDifDBFileName (2 character strings)

“radDifDBFileName”    Record tag.

radDifDBFileName      Name of output file of radiation and diffraction  
computations in Python pickle format.

### Record (e), Ship Loading Condition

“loadCondition”, waterDensity, draftBlMid, trimBlStern, shipKG (1 character string, 4 floats)

“loadCondition” Record tag.

waterDensity Water density ( $\text{kg}/\text{m}^3$ ).

draftBlMid Draft of baseline at midships (m).

trimBlStern Trim of baseline by stern (m).

shipKG Height of centre of gravity above baseline (m).

**Note:** The values in this record must agree with the values used for the wet panel hull file wetPanelFileName. Values are considered to be in agreement when they are within a tolerance of  $0.001 \text{ kg}/\text{m}^3$  for density, and  $0.001 \text{ m}$  for draft, trim, and height of CG. The output file from SM3DPanelHull gives the values of the above parameters.

### Record (f), Ship Radii of Gyration for Non-dimensional Hydrodynamic Coefficients

This record is optional. If the record is not included, then default values will be used.

“gyRadiiNom”, rollGyradius, pitchGyradius, yawGyradius (1 character string, 3 floats)

“gyRadiiOut” Record tag.

rollGyradius Ship roll gyradius (m). Default is  $0.4B_{max}$ , where  $B_{max}$  is determined from the maximum  $y$  value for the wet panelled hull.

pitchGyradius Ship pitch gyradius (m). Default is  $0.25L$ .

yawGyradius Ship yaw gyradius (m). Default is  $0.25L$ .

**Note:** These values are only used for non-dimensionalization of coefficients in the ASCII output file. These values do not affect the output dimensional values in the output database file radDifDBFileName.

### Record (g), Option for Saving Hydrodynamic Potentials and Source Strengths

This record is optional. If the record is not included, then potentials and source strengths are not saved.

“savePotOption”, savePotOption (2 character strings)

“savePotOption” Record tag.

savePotOption Option for saving radiation and diffraction potentials and source strengths:

savePot - Radiation and diffraction potentials source strengths are saved in output file radDifDBFileName (Record (d)). This option is recommended if subsequent computations require the inclusion of radiation and diffraction on relative vertical motion and wave kinematics near the ship.

noSavePot - Radiation and diffraction potentials and source strengths are not saved in file radDifDBFileName (default).

### Record (h), Limit on File Size with Hydrodynamic Potentials and Source Strengths

This record is optional. If the record is not included, then a default value is used.

“maxPotFileSizeMB”, maxPotFileSizeMB (1 character string, 1 float)

“maxPotFileSizeMB” Record tag.

maxPotFileSizeMB Limit on size (megabytes) of output file radDifDBFileName (Record (d)) with radiation and diffraction potentials. The default file size limit is 400 MB. The size of the output file in megabytes is estimated to be:

$$4.0 \times 10^{-6} N_{port}^2 + 0.0008 \times N_{port} \times N_{enfreq} + 0.0008 \times N_{port} \times N_{speed} \times N_{seadir} \times N_{wavefreq}$$

where  $N_{port}$  is the number of panels on the port side of the wetted hull surface,  $N_{enfreq}$  is the number of wave encounter frequencies,  $N_{speed}$  is the number of ship speeds,  $N_{seadir}$  is the number of relative sea directions, and  $N_{wavefreq}$  is the number of wave frequencies.

### Record (i), Options for Computing Hydrodynamic Coefficients

This record is optional. If the record is not included, then default values will be used.

“hydroCompOptions”, enFreqTrans, speedEnFreqMax, r2AreaThreshold, r2ImageAreaThreshold, sourceGaussOption, fieldGalerkinOption, orderGauss (1 character string, 4 floats, 2 character strings, 1 integer)

“hydroCompOptions”	Record tag.
enFreqTrans	Encounter frequency threshold for determining whether the frequency dependent Green function is determined relative to the zero frequency Green function or the infinite frequency Green function (default 0.0). A value of approximately $6\sqrt{g/L}$ is recommended.
speedEnFreqMax	Limit on $U/\omega_e$ for determining hydrodynamic forces at forward speed (default $10^6$ ).
rAreaThreshold	Limit on $R/\sqrt{A_s}$ for exact evaluation of $1/R$ from a source panel to a field point, where $A_s$ is source panel area (default 20.0).
rImageAreaThreshold	Limit on $R_1/\sqrt{A_s}$ for exact evaluation of $1/R_1$ from the image of a source panel to a field point (default 20.0).
sourceGaussOption	Option for using Gaussian quadrature from source for determining frequency dependent portion of Green function. noSourceGauss - Centroid of source is used. sourceGauss - Multiple points on source are used (default).
fieldGalerkinOption	Option for using Galerkin method with multiple points on field panel for evaluating Green functions. noGalerkin - Centroid of field panel is used. Galerkin - Multiple points on field panel are used (default).
orderGauss	Order of Gauss quadrature if used for source panel and/or field panel. Valid values are 1 (single point per panel), 2 (4 points, default), and 3 (9 points).

### Record (j1), Encounter Frequencies

One of Record (j1) or Record (j2) must be given.

“enFreqs”, enFreqs (1 character string, array of floats)

“enFreqs” Record tag.

enFreqs Array of encounter frequencies (rad/s).



### **Record (j2), Encounter Frequency Range**

One of Record (j1) or Record (j2) must be given.

“enFreqRange”, enFreqMin, enFreqMax, enFreqInc (1 character string, 3 floats)

“enFreqRange” Record tag.

enFreqMin Minimum encounter frequency (rad/s).

enFreqMax Maximum encounter frequency (rad/s).

enFreqInc Encounter frequency increment (rad/s).

**Note:** enFreqInc must be set such that there are no more than 1000 encounter frequencies.

### **Record (k), Encounter Frequencies for Removal**

This record is optional. If this Record is omitted, then no encounter frequencies are removed.

“enFreqsRemove”, enFreqsRemove (1 character string, array of floats)

“enFreqsRemove” Record tag.

enFreqsRemove Array of encounter frequencies to be removed from values given in Records (j1) or (j2) (rad/s). This record can be used for removing irregular frequencies. If this record is not specified, then no encounter frequencies are removed unless associated matrix condition numbers exceed limits specified below.

### **Record (l), Beginning of Condition Number Frequency Limits**

This record and the subsequent Records (l1) to (l5) are optional. If these Records are omitted, then parameters are set to defaults.

“begin condLimits” (1 character string with 2 words)

### **Record (l1), Encounter Frequencies for Longitudinal Mode Condition Number Limits**

This record is required if Record (l) has been used.

“enFreqsLongLimits”, enFreqsLongLimits (1 character strings, array of floats)

“enFreqsLongLimits” Record tag.

enFreqsLongLimits Array of encounter frequencies at which matrix condition number limits are specified for longitudinal source strengths (defaults 0.0 and  $10^6$ ).

### **Record (12), Longitudinal Mode Condition Number Limits**

This record is required if Record (1) has been used.

“condLimitsLong”, condLimitsLong (1 character strings, array of floats)

“condLimitsLong” Record tag.

condLimitsLong Array of longitudinal matrix condition number limits. This array must be the same length as enFreqsLongLimits in Record (11). (defaults  $10^6$  and  $10^6$ ).

### **Record (13), Encounter Frequencies for Lateral Mode Condition Number Limits**

This record is required if Record (1) has been used.

“enFreqsLatLimits”, enFreqsLatLimits (1 character strings, array of floats)

“enFreqsLatLimits” Record tag.

enFreqsLatLimits Array of encounter frequencies at which matrix condition number limits are specified for lateral source strengths (defaults 0.0 and  $10^6$ ).

### **Record (14), Lateral Mode Condition Number Limits**

This record is required if Record (1) has been used.

“condLimitsLat”, condLimitsLat (1 character strings, array of floats)

“condLimitsLat” Record tag.

condLimitsLat Array of lateral matrix condition number limits. This array must be the same length as enFreqsLatLimits in Record (13). (defaults  $10^6$  and  $10^6$ ).

### **Record (15), End of Condition Number Frequency Limits**

This record is required if Record (1) has been used.

“end condLimits” (1 character string with 2 words)

### **Record (m1), Ship Speed Range in m/s**

One of Records (m1) to (m6) must be given.

“speedRange”, speedMin, speedMax, speedInc (1 character string, 3 floats)

“speedRange” Record tag.

speedMin Minimum ship speed (m/s).

speedMax Maximum ship speed (m/s).

speedInc Increment for ship speed (m/s).

### **Record (m2), Ship Speeds in m/s**

One of Records (m1) to (m6) must be given.

“speeds”, speeds (1 character string, array of floats)

“speeds” Record tag.

speeds Array of ship speeds (m/s).

### **Record (m3), Ship Speed Range in Knots**

One of Records (m1) to (m6) must be given.

“speedKnotsRange”, speedKnotsMin, speedKnotsMax, speedKnotsInc (1 character string, 3 floats)

“speedKnotsRange” Record tag.

speedKnotsMin Minimum ship speed (knots).

speedKnotsMax Maximum ship speed (knots).

speedKnotsInc Increment for ship speed (knots).

### **Record (m4), Ship Speeds in Knots**

One of Records (m1) to (m6) must be given.

“speedsKnots”, speedsKnots (1 character string, array of floats)

“speedsKnots” Record tag.

speedsKnots Array of ship speeds (knots).

### **Record (m5), Froude Number Range**

One of Records (m1) to (m6) must be given.

“froudeRange”, froudeMin, froudeMax, froudeInc (1 character string, 3 floats)

“froudeRange” Record tag.

froudeMin Minimum Froude number.

froudeMax Maximum Froude number.

froudeInc Froude number increment.

### **Record (m6), Ship Froude Numbers**

One of Records (m1) to (m6) must be given.

“froudes”, froudes (1 character string, array of floats)

“froudes” Record tag.

froudes Array of ship Froude numbers.

### **Record (n1), Range of Sea Directions Relative to the Ship**

One of Records (n1) or (n2) must be given.

“seaDirDegRange”, seaDirDegMin, seaDirDegMax, seaDirDegInc (1 character string, 3 floats)

“seaDirDegRange” Record tag.

seaDirDegMin Minimum sea direction relative to ship (deg).

seaDirDegMax Maximum sea direction relative to ship (deg).

seaDirDegInc Increment sea direction relative to ship (deg).

### **Record (n2), Sea Directions Relative to the Ship**

One of Records (n1) or (n2) must be given.

“seaDirsDeg”, seaDirsDeg (1 character string, array of floats)

“seaDirsDeg” Record tag.

seaDirsDeg Array of sea directions relative to the ship (deg) .

### **Record (o1), Range of Incident Wave Frequencies**

One of Records (o1) or (o2) must be given.

“waveFreqRange”, waveFreqMin, waveFreqMax, waveFreqInc (1 character string, 3 floats)

“waveFreqRange” Record tag.

waveFreqMin Minimum incident wave frequency (rad/s).

waveFreqMax Maximum incident wave frequency (rad/s).

waveFreqInc Increment for incident wave frequency (rad/s).

### **Record (o2), Incident Wave Frequencies**

One of Records (o1) or (o2) must be given.

“waveFreqs”, waveFreqs (1 character string, array of floats)

“waveFreqs” Record tag.

waveFreqs Array of increasing incident wave frequencies (rad/s).

### **Record (p), Option for Wave Diffraction Computations**

“diffracOption”, diffracOption (2 character strings)

“diffracOption” Record tag.

diffracOption Option for completing diffraction computations.

diffrac - Diffraction computations will be completed.

noDiffrac - No diffraction computations.

### **Record (q), Plot Option**

“plotOption”, plotOption (2 character strings)  
“plotOption” Record tag.  
plotOption Option for making plots of hydrodynamic coefficients.  
noPlots - No plots are produced.  
screenFile - Plots are both plotted on the screen and to a file.  
screen - Plots are only plotted on the screen.  
file - Plots are only written to a file.

### **Record (q1), Plot File Name Prefix**

This record is optional. If the record is omitted, then no prefix is used.  
“plotNamePrefix”, plotNamePrefix (2 character strings)  
“plotNamePrefix” Record tag.  
plotNamePrefix Prefix for plot files (default is no prefix).

### **Record (q2), Plot File Format**

This record is optional. If the record is omitted, then png format is used.  
“fileFormat”, fileFormat (2 character strings)  
“fileFormat” Record tag.  
fileFormat Plot format. Available formats are bmp, eps, gif, pdf, png, ppm, ps, svg, tiff, and wmf.

### **Record (q3), Image Size**

This record is optional  
“plotSize”, widthmm, heightmm (1 character string, 2 floats)  
“plotSize” Record tag.  
widthmm Plot width (mm). (Default 120 mm)  
heightmm Plot height (mm). (Default 80 mm)  
**Note:** If this record is omitted, then the default values are used.

### **Record (r), End of Input File for SM3DRadDif**

“end SM3DRadDif” (1 character string with 2 words)

## B.2 Sample Input File for SM3DRadDif

```
begin SM3DRadDif
label Generic frigate
wetPanelFileName genFrigWetPanelHull.pkl
radDifDBFileName genFrigRadDifDB.pkl
loadCondition 1025.0 4.2 0.0 6.0
hydroCompOptions 1.5 1.0e6 20.0 20.0 sourceGauss Galerkin 2
enFreqRange 0.1 6.0 0.1
begin condLimits
    enFreqsLongLimits 1.0 6.0
    condLimitsLong    4000 4000
    enFreqsLatLimits  1.0  6.0
    condLimitsLat     1500 1500
end condLimits
speedKnotsRange 0.0 40.0 5.0
seaDirDegRange 0.0 180.0 15.0
waveFreqRange 0.1 2.0 0.1
diffracOption diffrac
plotOption screen
end SM3DRadDif
```

## B.3 Sample Output File for SM3DRadDif

Program SM3DRadDif

ShipMo3D library Version 1.0c - 26 November 2007

Time : Wed Feb 06 13:49:02 2008

Run label:

Generic frigate

\*\*\*\* ECHO OF USER INPUT \*\*\*\*

Input wet panel file name:

genFrigWetPanelHull.pkl

Radiation and diffraction database file name:

genFrigRadDifDB.pkl

Water density : 1025.000 kg/m3

Draft of baseline at midships : 4.200 m

Trim of baseline by stern : 0.000 m

Height of CG above baseline, KG : 6.000 m

Default nominal gyradii

Roll gyradius : 5.646 m

Pitch gyradius : 30.000 m

Yaw gyradius : 30.000 m

Option for saving potentials and source strengths : noSavePot (default)

Maximum file size for potentials and source strengths : 400.0 MB (default)

Parameters for computing hydrodynamic coefficients (input)

Green function transition frequency : 1.500 rad/s

Limit on U/enFreq : 1000000.0

R threshold for exact integration : 20.0

R1 threshold for exact integration : 20.0

Source panel Gauss option : sourceGauss

Field panel Galerkin option : Galerkin

Order for Gauss quadrature : 2

Encounter frequency range

Minimum : 0.100 (rad/s)

Maximum : 6.000 (rad/s)

Increment : 0.100 (rad/s)

User input limits on matrix condition numbers

Matrix condition number limits for longitudinal motions

Encounter frequency (rad/s)	Condition number limit
1.000	4000.0
6.000	4000.0

Matrix condition number limits for lateral motions

Encounter frequency (rad/s)	Condition number limit
1.000	1500.0
6.000	1500.0

Speed range

Minimum	:	0.000 knots
Maximum	:	40.000 knots
Increment	:	5.000 knots

Sea direction range

Minimum	:	0.000 deg
Maximum	:	180.000 deg
Increment	:	15.000 deg

Incident wave frequency range

Minimum	:	0.100 rad/s
Maximum	:	2.000 rad/s
Increment	:	0.100 rad/s

Wave diffraction computation option : diffrac

Plot option : screen

Plot file format : png

Plot width : 120 mm

Plot height : 80 mm

\*\*\*\* COMPUTED HYDRODYNAMIC COEFFICIENTS\*\*\*\*

Time for computing coefficients: 5551 s

Summary of hydrodynamic coefficients at zero speed

Added mass non-dimensionalised by modal inertia.

Damping non-dimensionalised by (modal inertia\*encounter frequency).

Ship mass	:	3716329.367 kg
Roll gyradius	:	5.646 m
Pitch gyradius	:	30.000 m
Yaw gyradius	:	30.000 m

Longitudinal modes

Encounter frequency	Surge Added Damping	Heave Added Damping	Pitch Added Damping	Condition number
---------------------	---------------------	---------------------	---------------------	------------------



rad/s	mass		mass		mass		
0.000	0.019	0.000	4.422	0.000	2.585	0.000	
0.100	0.020	0.000	4.638	0.247	2.615	0.007	10.6
0.200	0.020	0.000	4.770	0.888	2.703	0.031	10.7
0.300	0.022	0.001	4.536	1.650	2.874	0.116	11.0
0.400	0.024	0.003	3.966	2.248	3.093	0.370	11.8
0.500	0.025	0.007	3.233	2.543	3.175	0.843	13.3
0.600	0.023	0.011	2.515	2.518	2.953	1.363	15.5
0.700	0.019	0.014	1.983	2.252	2.480	1.697	18.6
0.800	0.015	0.013	1.688	1.940	1.948	1.729	22.6
0.900	0.012	0.012	1.520	1.694	1.587	1.542	27.2
1.000	0.011	0.011	1.392	1.492	1.409	1.360	32.4
1.100	0.010	0.011	1.302	1.304	1.279	1.227	38.1
1.200	0.009	0.010	1.245	1.139	1.180	1.095	44.1
1.300	0.008	0.009	1.209	0.992	1.114	0.979	50.7
1.400	0.008	0.008	1.190	0.863	1.065	0.874	57.8
1.500	0.007	0.008	1.175	0.766	1.019	0.801	69.2
1.600	0.007	0.007	1.175	0.667	0.996	0.720	80.5
1.700	0.007	0.007	1.178	0.580	0.980	0.649	137.2
1.800	0.006	0.006	1.132	0.484	0.965	0.584	812.1
1.900	0.006	0.006	1.289	0.450	0.968	0.535	1571.9
2.000	0.006	0.005	1.264	0.390	0.958	0.488	1020.2
2.100	0.006	0.005	1.280	0.338	0.934	0.439	2222.6
2.200	0.005	0.004	1.303	0.305	0.950	0.334	3494.9
2.400	0.006	0.003	1.330	0.239	1.015	0.304	1584.5
2.500	0.006	0.003	1.344	0.211	1.024	0.284	1309.0
2.600	0.006	0.003	1.348	0.181	1.033	0.264	1401.6
2.700	0.006	0.003	1.411	0.161	1.047	0.246	2001.7
2.800	0.006	0.003	1.401	0.144	1.062	0.238	2230.8
2.900	0.006	0.003	1.429	0.130	1.056	0.220	1483.6
3.000	0.006	0.002	1.436	0.121	1.072	0.200	1890.6
3.100	0.006	0.002	1.452	0.111	1.085	0.180	1758.0
3.200	0.006	0.002	1.459	0.100	1.110	0.176	2171.3
3.300	0.006	0.002	1.474	0.086	1.110	0.170	1928.1
3.400	0.006	0.002	1.498	0.088	1.129	0.155	2291.3
3.500	0.006	0.002	1.507	0.082	1.152	0.153	1899.5
3.600	0.006	0.002	1.520	0.076	1.168	0.153	1964.3
3.700	0.007	0.001	1.532	0.075	1.198	0.151	2031.0
3.800	0.007	0.002	1.550	0.075	1.228	0.169	2425.9
4.000	0.007	0.001	1.576	0.065	1.271	0.150	1643.5
4.400	0.006	0.001	1.362	0.031	0.564	0.067	1830.0
4.500	0.006	0.001	1.431	0.021	0.755	0.037	1295.0
4.700	0.006	0.001	1.486	0.022	0.914	0.044	1128.2
4.800	0.007	0.001	1.490	0.024	0.920	0.056	1369.4
4.900	0.007	0.001	1.495	0.011	0.922	0.028	1253.1

5.000	0.007	0.001	1.510	0.010	0.958	0.016	724.2
5.100	0.007	0.001	1.516	0.007	0.973	0.009	639.5
5.200	0.007	0.000	1.522	0.004	0.987	0.002	508.0
5.300	0.007	0.000	1.529	-0.000	1.003	-0.005	432.8
5.400	0.007	0.000	1.537	0.002	1.014	-0.002	484.1
5.500	0.007	0.000	1.536	0.003	1.010	0.000	462.4
5.600	0.007	0.000	1.529	-0.007	1.006	-0.019	430.0
5.700	0.007	-0.000	1.540	-0.013	1.002	-0.053	416.7
5.800	0.007	-0.000	1.553	-0.024	1.029	-0.066	508.9
5.900	0.007	-0.000	1.558	-0.027	1.055	-0.075	545.4
6.000	0.007	-0.000	1.569	-0.031	1.075	-0.093	638.5
Infinite	0.008	0.000	1.677	0.000	1.281	0.000	

Lateral modes

Encounter frequency rad/s	Sway		Roll		Yaw		Condition number
	Added mass	Damping	Added mass	Damping	Added mass	Damping	
0.000	0.673	0.000	0.109	0.000	0.623	0.000	
0.100	0.676	0.000	0.110	0.000	0.625	0.000	20.2
0.200	0.686	0.000	0.110	0.000	0.631	0.000	20.4
0.300	0.705	0.002	0.111	0.000	0.641	0.000	20.7
0.400	0.738	0.010	0.113	0.000	0.658	0.001	21.3
0.500	0.783	0.036	0.116	0.001	0.685	0.004	22.2
0.600	0.832	0.091	0.119	0.004	0.727	0.018	23.5
0.700	0.861	0.180	0.122	0.009	0.780	0.059	25.3
0.800	0.850	0.284	0.123	0.016	0.818	0.140	27.8
0.900	0.803	0.378	0.121	0.022	0.812	0.236	31.1
1.000	0.730	0.452	0.119	0.027	0.775	0.316	35.5
1.100	0.640	0.497	0.115	0.033	0.724	0.385	41.1
1.200	0.553	0.513	0.109	0.037	0.652	0.436	48.2
1.300	0.473	0.510	0.103	0.039	0.578	0.462	56.9
1.400	0.404	0.491	0.097	0.040	0.504	0.472	67.4
1.500	0.346	0.457	0.091	0.039	0.430	0.447	109.2
1.600	0.301	0.427	0.086	0.037	0.374	0.430	127.6
1.700	0.266	0.395	0.082	0.035	0.328	0.406	148.1
1.800	0.239	0.363	0.079	0.032	0.292	0.379	170.1
1.900	0.219	0.333	0.077	0.030	0.263	0.350	194.2
2.000	0.203	0.305	0.075	0.027	0.242	0.322	218.4
2.100	0.191	0.278	0.074	0.025	0.225	0.296	241.5
2.200	0.178	0.253	0.072	0.023	0.212	0.272	262.4
2.400	0.181	0.210	0.073	0.019	0.194	0.231	693.6
2.500	0.177	0.193	0.072	0.018	0.197	0.200	816.9
2.600	0.170	0.174	0.072	0.016	0.194	0.189	1122.2
2.700	0.177	0.157	0.072	0.015	0.190	0.175	756.0
2.800	0.176	0.144	0.072	0.014	0.186	0.155	1069.2

2.900	0.175	0.132	0.072	0.013	0.192	0.143	790.1
3.000	0.173	0.074	0.071	0.011	0.191	0.131	1423.4
3.100	0.184	0.107	0.072	0.011	0.193	0.120	971.8
3.200	0.188	0.102	0.073	0.010	0.199	0.108	888.1
3.300	0.191	0.092	0.073	0.010	0.199	0.099	861.9
3.400	0.194	0.084	0.073	0.009	0.201	0.091	938.5
3.500	0.194	0.076	0.074	0.009	0.205	0.085	992.1
3.600	0.194	0.067	0.074	0.008	0.207	0.077	934.4
3.700	0.212	0.063	0.074	0.008	0.210	0.069	779.0
3.800	0.208	0.060	0.074	0.008	0.214	0.064	817.3
4.000	0.211	0.050	0.075	0.009	0.219	0.055	1031.3
4.400	0.224	0.037	0.081	0.012	0.229	0.039	711.3
4.500	0.225	0.033	0.083	0.023	0.232	0.036	1393.3
4.700	0.238	0.018	0.061	0.003	0.235	0.029	793.8
4.800	0.236	0.026	0.067	0.002	0.239	0.027	576.0
4.900	0.236	0.024	0.069	0.003	0.241	0.025	635.5
5.000	0.236	0.021	0.068	0.002	0.243	0.023	738.1
5.100	0.236	0.014	0.069	0.001	0.245	0.022	524.2
5.200	0.247	0.017	0.070	0.001	0.247	0.019	423.4
5.300	0.245	0.017	0.071	0.001	0.249	0.017	398.6
5.400	0.245	0.014	0.071	0.000	0.251	0.015	410.3
5.500	0.246	0.008	0.072	0.000	0.254	0.013	391.1
5.600	0.259	0.015	0.072	0.000	0.258	0.013	406.3
5.700	0.251	0.016	0.072	-0.001	0.259	0.015	380.1
5.800	0.250	0.013	0.073	-0.001	0.259	0.015	370.6
5.900	0.253	0.007	0.073	-0.001	0.259	0.013	390.4
6.000	0.258	0.011	0.074	-0.002	0.260	0.012	499.9
Infinite	0.299	0.000	0.082	0.000	0.307	0.000	

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# Annex C: Files for Building Ship with SM3DBuildShip

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## C.1 Format of Input Ship File for SM3DBuildShip

### Record (a), Beginning Record

“begin SM3DBuildShip”(1 character string with 2 words)

### Record (b), Run Label

“label”, label (2 character strings)

“label” Record tag.

label Label for run. This can include spaces.

### Record (c), Ship Type

“shipType”, shipType (2 character strings)

“shipType” Record tag.

shipType Option for ship type.

steadyFD - Ship with nominally steady heading and speed for frequency domain computations.

freeTD - Freely maneuvering ship for time domain computations with SM3DFreeShip.

### Record (d), Radiation and Diffraction Database File Name

“radDifDBFileName”, radDifDBFileName (2 character strings)

“radDifDBFileName” Record tag.

radDifDBFileName Name of file of radiation and diffraction computations in Python pickle format. This file should be produced by SM3DRadDif before running SM3DBuildShip.

### Record (e), Output Ship Database File Name

“shipDBFileName”, shipDBFileName (2 character strings)

“shipDBFileName” Record tag.

shipDBFileName Name of output ship database file in Python pickle format.

### Record (f), Dry Panel Hull Option

“dryPanelOption”, dryPanelOption (2 character strings)  
“dryPanelOption” Record tag.  
dryPanelOption Option for including dry panel hull.  
dryPanel - Dry panel hull is included.  
noDryPanel - Dry panel hull is not included.

**Note:** Option dryPanel must be selected for time domain simulations that include nonlinear hull forces due to incident waves and buoyancy. If option dryPanel is selected and the shipType in Record (c) is set to steadyFD, then the dry panel hull will not be used for computations and will not be plotted as part of the ship.

### Record (f1), Dry Panel Hull File Name

This record is only required if dryPanelOption is set to dryPanel in Record (f)  
“dryPanelFileName”, dryPanelFileName (2 character strings)  
“dryPanelFileName” Record tag.  
dryPanelFileName Name of input file describing hull in Python pickle format.

### Record (g), Load Condition

“loadCondition”, waterDensity, draftBlMid, trimBlStern, shipKG (1 character string, 4 floats)  
“waterDensity” Record tag.  
waterDensity Water density ( $\text{kg/m}^3$ ).  
draftBlMid Draft of baseline at midships (m).  
trimBlStern Trim of baseline by stern (m).  
shipKG Height of centre of gravity above baseline (m).

**Note:** The values in this record must agree with the values used for the radiation and diffraction database file radDifDBFileName. Values are considered to be in agreement when they are within a tolerance of  $0.001 \text{ kg/m}^3$  for density, and  $0.001 \text{ m}$  for draft, trim, and height of CG.

### **Record (h), Correction to Metacentric Height**

“correctionGM”, correctionGM (1 character string, 1 float)  
“correctionGM” Record tag.  
correctionGM Correction to metacentric height (m). A negative value can be used to model tank free surface effects.

### **Record (i), Mass Gyradii**

“gyradii”, rollGyradius, pitchGyradius, yawGyradius (1 character string, 3 floats)  
“gyradii” Record tag.  
rollGyradius Roll radius of gyration (m).  
pitchGyradius Pitch radius of gyration (m).  
yawGyradius Yaw radius of gyration (m).

### **Record (j), Time Increment and Maximum Value for Hull Hydrodynamic Retardation Forces**

“tRetardIncMax”, tRetardInc, tRetardMax (1 character string, 2 floats)  
“tRetardIncMax” Record tag.  
tRetardInc Time increment for hull hydrodynamic retardation forces (s).  
A value of approximately  $0.05\sqrt{L/g}$  is recommended.  
tRetardMax Maximum time for hull hydrodynamic retardation forces (s).  
A value of approximately  $5\sqrt{L/g}$  is recommended.

### **Record (k), Encounter Frequency Increment and Maximum Value for Integration of Hull Hydrodynamic Retardation Functions**

“enFreqIntIncMax”, enFreqIntInc, enFreqIntMax (1 character string, 2 floats)  
“enFreqIntIncMax” Record tag.  
enFreqIntInc Increment of encounter frequency for computation of retardation forces using integration of frequency domain coefficients. A value of approximately  $0.4\sqrt{g/L}$  is recommended.  
enFreqIntMax Maximum encounter frequency for computation of retardation forces using integration of frequency domain coefficients. This value should typically correspond with the maximum encounter frequency in the radiation and diffraction database of Record (d). A value of approximately  $20\sqrt{g/L}$  is recommended.

### **Record (1), Beginning of Hull Viscous Data**

“begin hullViscous” (1 character string with 2 words)

### **Record (11), Ship Speeds in m/s for Resistance Coefficients**

One of Records (11) or (12) must be given.

“speedsResist”, speedsResist (1 character string, array of floats)

“speedsResist”    Record tag.

speedsResist      Array of ship speeds (m/s).

### **Record (12), Ship Speeds in Knots for Resistance Coefficients**

One of Records (11) or (12) must be given.

“speedsResistKnots”, speedsResistKnots (1 character string, array of floats)

“speedsResistKnots”    Record tag.

speedsResistKnots      Array of ship speeds (knots).

### **Record (13), Ship Resistance Option**

“resistOption”, resistOption (2 character strings)

“resistOption”    Record tag.

resistOption      Option for computing ship resistance.

HoltropMennen - Ship resistance is computed using the method of Holtrop and Mennen as described in Holtrop [16]. This method is suitable for conventional monohull vessels, including those having a bulbous bow.

InputResist - Input ship resistance coefficients are read from Record (16).



### Record (14), Hull Dimensions for Computing Ship Resistance

This record can optionally be included if resistOption is set to HoltropMennen in Record (13). If the record is omitted, then values will be set to defaults based on the ship wetted geometry.

“hullResistDim”, draftMidResist, beamResist, CblockResist, CwaterplaneResist, areaTransomResist, areaMidshipsResist (1 character string, 6 floats)

“hullResistDim”	Record tag.
draftMidResist	Hull draft at midships (m). The default is draftBlMid from Record (g).
beamResist	Hull beam (m). The default is twice the maximum panel $y$ value from the radiation and diffraction database file of Record (d).
CblockResist	Hull block coefficient $C_B$ . The default is based on the wet panelled hull in the radiation and diffraction database file.
CwaterplaneResist	Hull waterplane area coefficient $C_W$ . The default is based on the wet panelled hull in the radiation and diffraction database file.
areaTransomResist	Cross-sectional area of hull transom (m <sup>2</sup> ).
areaMidshipsResist	Cross-sectional area of hull at midships (m <sup>2</sup> ).
<b>Note:</b>	This record should be given as input if the draft and trim of the hull differ significantly from the draft and trim of the baseline.

### Record (15), Bulbous Bow Dimensions for Computing Ship Resistance

This record can optionally be included if resistOption is set to HoltropMennen in Record (13). If the record is omitted, then it is assumed that the ship has no bulbous bow.

“bulbousBowDim”, areaBulbousBow, zBlBulbousBow, zBlKeelBow (1 character string, 3 floats)

“bulbousBowDim”	Record tag.
areaBulbousBow	Cross-sectional area of the bulbous bow (m <sup>2</sup> ).
zBlBulbousBow	Height of the centre of the bulbous bow above the baseline (m).
zBlKeelBow	The height of the ship keel above the baseline at the longitudinal location of the bulbous bow (m).

### **Record (16), Ship Resistance Coefficients**

This Record must only be given if resistOption is set to InputResist in Record (13).

“resistCos”, resistCos (1 character string, array of floats)

“resistCos” Record tag.

resistCos Ship non-dimensional resistance coefficients. The resistance coefficients are non-dimensionalized by  $1/2 \rho A_w U^2$ . The number of input resistance coefficients must correspond with the number of ship speeds in Record (11) or (12).

### **Record (17), Hull Eddy and Lateral Drag Coefficients**

This record is optional. If this Record is not given, then parameters are set to defaults.

“hullDragCo”, dragCoEddy, dragCoLateral (1 character strings, 2 floats)

“hullDragCo” Record tag.

dragCoEddy Eddy drag coefficient for roll motion (default 1.17).

dragCoLateral Lateral drag coefficient (default 0.0). Note that lateral drag forces are normally included in nonlinear maneuvering force coefficients, and that the lateral drag coefficient should be zero in such cases.

### **Record (18), End of Hull Viscous Force Data**

“end hullViscous” (1 character string with 2 words)

### **Record (m), Beginning of Hull Maneuvering Force Data**

“begin hullManeuver” (1 character string with 2 words)

### Record (m1), Hull Dimensions for Computing Maneuvering Coefficients

This record is optional. If the record is omitted, then values will be set to defaults.

“hullManeuverDim”, draftMidMan, trimSternMan, beamMan, CblockMan, zWlMan (1 character string, 5 floats)

“hullManeuverDim”	Record tag.
draftMidMan	Hull draft at midships (m). The default is draftBlMid from Record (g).
trimSternMan	Hull trim by stern (m). The default is trimBlStern from Record (g).
beamMan	Hull maximum beam (m). The default is twice the maximum panel $y$ value from the radiation and diffraction database file of Record (d).
CblockMan	Hull block coefficient $C_B$ . The default is based on the wet panelled hull in the radiation and diffraction database file.
zWlMan	$z$ coordinate of maneuver force relative to the ship waterline. The default is 0.0.
<b>Note:</b>	This record should be given as input if the draft and trim of the hull differ significantly from the draft and trim of the baseline.

### Record (m2), Hull Maneuvering Coefficient Method

“hullManMethod”, hullManMethod (2 character strings)

“hullManMethod”	Record tag.
hullManMethod	Method for evaluating hull maneuvering coefficients. inputManCo - Input hull maneuvering coefficients are given. Inoue - Hull maneuvering coefficients are computed based on Inoue et al. [9].

### Record (m2a), Nondimensional Hull Maneuvering Coefficients

This record is required if hullManMethod is set to inputManCo in Record (m2).

“hullManCo”, Yv, Yr, Nv, Nr, Yvv, Yvr, Yrr, Nvr2, Nrr, Nrv2 (1 character strings, 10 floats)

“hullManCo” Record tag.

Yv	Linear sway-sway force coefficient $Y'_v$ .
Yr	Linear sway-yaw force coefficient $Y'_r$ .
Nv	Linear yaw-sway force coefficient $N'_v$ .
Nr	Linear yaw-yaw force coefficient $N'_r$ .
Yvv	Nonlinear sway-sway force coefficient $Y'_{v v }$ .
Yvr	Nonlinear sway-sway force coefficient $Y'_{v r }$ .
Yrr	Nonlinear sway-yaw force coefficient $Y'_{r r }$ .
Nvr2	Nonlinear yaw-sway force coefficient $N'_{vr^2}$ .
Nrr	Nonlinear yaw-yaw force coefficient $N'_{r r }$ .
Nrv2	Nonlinear yaw-yaw force coefficient $N'_{rv^2}$ .

### Record (m2b), Options for Input Hull Maneuvering Coefficients Provided in Record (m2a)

This record is optional if hullManMethod is set to inputManCo in Record (m2).

“inputManCoOptions”, inputManCoAxesOption, inputManCoEnFreqOption (3 character strings)

“inputManCoOptions”	Record tag.
inputManCoAxesOption	Option for input axes system for input hull maneuvering coefficients.  stabilityAxes - Input maneuvering coefficients are given for stability axes (default). translatingEarthAxes - Input maneuvering coefficients are given for translating earth axes.
inputManCoEnFreqOption	Option for encounter frequency for input hull maneuvering coefficients.  zero - Input maneuvering coefficients are for low frequency motions (default). infinite - Input maneuvering coefficients are for high frequency motions.

### **Record (m2c), Increments to Nondimensional Hull Maneuvering Coefficients Evaluated Using the Method of Inoue et al.**

This record is optional and can be used if hullManMethod is set to Inoue in Record (m2).

“deltaManCos”, deltaYv, deltaYr, deltaNv, deltaNr, deltaYvv, deltaYvr, deltaYrr, deltaNvr2, deltaNrr, deltaNrv2 (1 character strings, 10 floats)

“deltaManCos” Record tag.

deltaYv Increment to sway-sway maneuvering force coefficient  $Y'_v$ .

deltaYr Increment to sway-yaw maneuvering force coefficient  $Y'_r$ .

deltaNv Increment to yaw-sway maneuvering force coefficient  $N'_v$ .

deltaNr Increment to sway-sway maneuvering force coefficient  $N'_r$ .

deltaYvv Increment to nonlinear maneuvering force coefficient  $Y'_{v|v|}$ .

deltaYvr Increment to sway-sway maneuvering force coefficient  $Y'_{v|r|}$ .

deltaYrr Increment to sway-sway maneuvering force coefficient  $Y'_{r|r|}$ .

deltaNvr2 Increment to sway-sway maneuvering force coefficient  $N'_{vr^2}$ .

deltaNrr Increment to sway-sway maneuvering force coefficient  $N'_{r|r|}$ .

deltaNrv2 Increment to sway-sway maneuvering force coefficient  $N'_{rv^2}$ .

**Note:** If this record is omitted, then all of the above values are set to 0.0.

### **Record (m3), End of Hull Maneuvering Force Data**

“end hullManeuver” (1 character string with 2 words)

### **Record (n), Beginning of Appendage Data**

“begin appendages” (1 character string with 2 words)

### **Record (n1), Beginning of Bilge Keel Data**

Records (n1) to (n1m) are optional, and can be repeated for each bilge keel or pair of bilge keels.

“begin bilgeKeel” (1 character string with 2 words)

### **Record (n1a), Pair Option**

This record must follow Record (n1).

“pairOption”, pairOption (2 character strings)

“pairOption” Record tag.

pairOption Option for input of single bilge keel or pair of bilge keels.  
single - Input given for a single bilge keel.  
pair - Input is used to create a pair of bilge keels. Input dimensions should be provided for the port bilge keel.

### **Record (n1b), Bilge Keel Label**

This record must follow Record (n1a).

“label” label (2 character strings)

“label” Record tag.

label Label for bilge keel. This can include spaces. If pairOption is set to pair in Record (n1a), then the port and starboard bilge keel labels will be appended with “(port)” and “(starboard)” respectively.

### **Record (n1c), Bilge Keel Stations**

This record must follow Record (n1b).

“stations” stations (1 character string, array of floats)

“stations” Record tag.

stations Stations (increasing) for which bilge keel coordinates are given.

### **Record (n1d), Lateral Coordinates of Bilge Keel at Root**

This record must follow Record (n1c).

“yRoots” yRoots (1 character string, array of floats)

“yRoots” Record tag.

yRoots Lateral offsets of bilge keel root. Input values correspond with stations in Record (n1c). If pairOption is set to pair in Record (n1), then a factor of  $-1.0$  will be applied to the starboard bilge yRoot values.

### **Record (n1e), Vertical Coordinates of Bilge Keel at Root**

This record must follow Record (n1d).

“zBlRoots” zBlRoots (1 character string, array of floats)

“zBlRoots” Record tag.

zBlRoots Vertical coordinate of bilge keel root relative to baseline. Input values correspond with stations in Record (n1c).

### **Record (n1f), Spans of Bilge Keel at Root**

This record must follow Record (n1e).

“spans” spans (1 character string, array of floats)

“spans” Record tag.

spans Bilge keel spans. Input values correspond with stations in Record (n1c).

### **Record (n1g), Bilge Keel Dihedral Angles**

This record must follow Record (n1f).

“dihedralsDeg” dihedralsDeg (1 character string, array of floats)

“dihedralsDeg” Record tag.

dihedralsDeg Bilge keel dihedral angles (0° oriented to port, 90° oriented upward). Port bilge keels typically have dihedral angles of approximately  $-45^\circ$ , and starboard bilge keels typically have dihedral angles of approximately  $-135^\circ$ . Input values correspond with stations in Record (n1c). If pairOption is set to pair in Record (n1), then dihedral angles for the starboard side are evaluated as  $(180^\circ - \text{dihedralsDeg})$ .

### **Record (n1h), Bilge Keel Inclusion of Added Mass Option**

This record is optional.

“addedMassOption” addedMassOption (2 character strings)

“addedMassOption” Record tag.

addedMassOption Option for including bilge keel added mass.  
includeAddedMass - added mass is included in bilge keel computations (default).  
excludeAddedMass - added mass is excluded in bilge keel computations. This option is intended to be used only in rare cases when the bilge keel added mass is already modelled elsewhere, such as when the bilge keel is modelled as part of the ship hull.

### **Record (n1i), Bilge Keel Roll Damping Parameters**

This record is optional, and can follow Record (n1g). If the record is not included, then defaults are used.

“bilgeKeelDamp”, dragCoMethod, wakeFraction, rollVelocityRatio (2 character strings, 2 floats)

“bilgeKeelDamp”	Record tag.
dragCoMethod	Method for determining bilge keel roll drag coefficient. Ikeda - Ikeda’s method (default). Constant - Constant (independent of roll amplitude and velocity). The input drag coefficient is given in Record (n1j). SimplifiedKatoAmplitude - Simplified Kato method, with drag coefficient decreasing as roll amplitude increases. SimplifiedKatoVelocity - Simplified Kato method, with drag coefficient decreasing as roll velocity increases. AmplitudeDecay - Drag coefficient decreasing as roll amplitude increases. Input parameters are given in Record (n1k). VelocityDecay - Drag coefficient decreasing as roll velocity increases. Input parameters are given in Record (n1l).
wakeFraction	Influence of local flow effects on reducing velocity due to ship forward speed (default 0.0).
rollVelocityRatio	Influence of local flow effects on flow velocity due to ship roll (default 1.0).

### **Record (n1j), Bilge Keel Drag Coefficient**

This record is required if dragCoMethod has been set to Constant in Record (n1i).

“bilgeKeelDragCo”, dragCoRef (1 character string, 1 float)

“bilgeKeelDragCo”	Record tag.
dragCoRef	Drag coefficient.



### **Record (n1k), Bilge Keel Damping Amplitude Decay Parameters**

This record is required if dragCoMethod has been set to AmplitudeDecay in Record (n1i).

“bilgeKeelAmpDecay”, dragCoRef, rollAmpRefDeg, alphaDecayDragCo (1 character string, 3 floats)

“bilgeKeelAmpDecay” Record tag.

dragCoRef Reference drag coefficient.

rollAmpRefDeg Reference roll amplitude (deg).

alphaDecayDragCo Reference drag decay coefficient. This value should be  $\geq 0.0$ .

### **Record (n1l), Bilge Keel Damping Velocity Decay Parameters**

This record is required if dragCoMethod has been set to VelocityDecay in Record (n1i).

“bilgeKeelVelDecay”, dragCoRef, rollVelAmpRefDeg, alphaDecayDragCo (1 character string, 3 floats)

“bilgeKeelVelDecay” Record tag.

dragCoRef Reference drag coefficient.

rollVelAmpRefDeg Reference roll velocity amplitude (deg/s).

alphaDecayDragCo Reference drag decay coefficient.

### **Record (n1m), End of Bilge Keel Data**

This record must be entered at the end of data for a bilge keel.

“end bilgeKeel” (1 character string with 2 words)

### **Record (n2), Beginning of Static Foil Data**

Records (n2) to (n2g) are optional, and can be repeated for each static foil or static foil pair.

“begin foil” (1 character string with 2 words)

### **Record (n2a), Pair Option**

This record must follow Record (n2).

“pairOption”, pairOption (1 character string with 2 words)

“pairOption” Record tag.

pairOption Option for input of single static foil or pair of static foils.  
single - Input given for a single static foil.  
pair - Input is used to create a pair of static foils. Input dimensions should be provided for the port static foil.

### **Record (n2b), Static Foil Label**

This record must follow Record (n2a).

“label” label (2 character strings)

“label” Record tag.

label Label for static foil. This can include spaces. If pairOption is set to pair in Record (n2a), then the port and starboard static foil labels will be appended with “(port)” and “(starboard)” respectively.

### **Record (n2c), Static Foil Dimensions**

This must follow Record (n2b).

“dimen”, station, yRoot, zBlRoot, span, chordRoot, chordTip, dihedralDeg  
(1 character string, 7 floats)

“dimen” Record tag.

station Station of centroid.

yRoot Lateral offset of root (m, +port).

zBlRoot Vertical coordinate of root relative to baseline (m, +up).

span Span (m).

chordRoot Chord length at root (m).

chordTip Chord length at tip (m).

dihedralDeg Dihedral angle (deg).

### **Record (n2d), Static Foil Inclusion of Added Mass Option**

This record is optional. If this record is not included, then a default value is used.

“addedMassOption” addedMassOption (2 character strings)

“addedMassOption” Record tag.

addedMassOption Option for including static foil added mass.

includeAddedMass - added mass is included in static foil computations (default).

excludeAddedMass - added mass is excluded in static foil computations. This option is intended to be used only in cases when the static foil added mass is already modelled elsewhere, such as when the static foil is modelled as part of the ship hull. For example, a submarine sail could be modelled as part of the panelled ship hull, and it could also be modelled as a static foil of zero added mass to obtain lift forces.

### **Record (n2e), Static Foil Wake Fraction**

This record is optional. If this record is not included, then a default value is used.

“wakeFraction”, wakeFraction (1 character string, 1 float)

“wakeFraction”    Record tag.

wakeFraction      Influence of local flow effects on reducing flow velocity due to ship forward speed (default 0.0).

### **Record (n2f), Static Foil Lift and Drag Coefficients**

This record is optional. If this record is not included, then default values are used.

“liftDragCo”, liftCoSlope, dragCo (1 character string, 2 floats)

“liftDragCo”      Record tag.

liftCoSlope        Lift curve slope  $\partial C^{lift}/\partial \alpha$  (/rad). If this record is omitted, then a default value is computed based on the foil aspect ratio.

dragCoNormal      Drag coefficient for flow normal to the foil face (default 1.17)

### **Record (n2g), End of Static Foil Data**

This record must follow Record (n2c) or (n2f).

“end foil” (1 character string with 2 words)

### **Record (n3), Beginning of Skeg Data**

Records (n3) to (n3m) are optional, and can be repeated for each skeg or skeg pair.

“begin skeg” (1 character string with 2 words)

### **Record (n3a), Pair Option**

This record must follow Record (n3).

“pairOption”, pairOption (1 character string with 2 words)

“pairOption”    Record tag.

pairOption        Option for input of single skeg or pair of skegs.

single - Input given for a single skeg.

pair - Input is used to create a pair of skegs. Input dimensions should be provided for the port skeg.

### **Record (n3b), Skeg Label**

This record must follow Record (n3a).

“label” label (2 character strings)

“label” Record tag.

label Label for Skeg. This can include spaces. If pairOption is set to pair in Record (n3a), then the port and starboard skeg labels will be appended with “(port)” and “(starboard)” respectively.

### **Record (n3c), Skeg Stations**

This record must follow Record (n3b).

“stations” stations (1 character string, array of floats)

“stations” Record tag.

stations Stations (increasing) for which skeg coordinates are given.

### **Record (n3d), Lateral Coordinates of Skeg at Root**

This record must follow Record (n3c).

“yRoots” yRoots (1 character string, array of floats)

“yRoots” Record tag.

yRoots Lateral offsets of skeg root. Input values correspond with stations in Record (n3c).

### **Record (n3e), Vertical Coordinates of Skeg at Root**

This record must follow Record (n3d).

“zBlRoots” zBlRoots (1 character string, array of floats)

“zBlRoots” Record tag.

zBlRoots Vertical coordinate of skeg root relative to baseline. Input values correspond with stations in Record (n3c).

### **Record (n3f), Spans of Skeg at Root**

This record must follow Record (n3e).

“spans” spans (1 character string, array of floats)

“spans” Record tag.

spans Skeg spans. Input values correspond with stations in Record (n3c).

### **Record (n3g), Skeg Dihedral Angles**

This record must follow Record (n3f).

“dihedralsDeg” dihedralsDeg (1 character string, array of floats)

“dihedralsDeg” Record tag.

dihedralsDeg Skeg dihedral angles (0° oriented to port, 90° oriented upward).  
Skegs typically have dihedral angles of approximately  $-90^\circ$ .  
Input values correspond with stations in Record (n3c).

### **Record (n3h), Skeg Inclusion of Added Mass Option**

This record is optional.

“addedMassOption” addedMassOption (2 character strings)

“addedMassOption” Record tag.

addedMassOption Option for including skeg added mass.  
includeAddedMass - added mass is included in skeg computations (default).  
excludeAddedMass - added mass is excluded in skeg computations. This option is intended to be used only in cases when the skeg added mass is already modelled elsewhere, such as when the skeg is modelled as part of the ship hull.

### **Record (n3i), Skeg Roll Damping Parameters**

This record is optional. If the record is not included, then defaults are used.

“skegDamp”, dragCoMethod, wakeFraction, rollVelocityRatio (2 character string, 2 floats)

“skegDamp”	Record tag.
dragCoMethod	Method for determining skeg roll drag coefficient. Ikeda - Ikeda’s method (default). Constant - Constant (independent of roll amplitude and velocity). The input drag coefficient is given in Record (n3j). SimplifiedKatoAmplitude - Simplified Kato method, with drag coefficient decreasing as roll amplitude increases. SimplifiedKatoVelocity - Simplified Kato method, with drag coefficient decreasing as roll velocity increases. AmplitudeDecay - Drag coefficient decreasing as roll amplitude increases. Input parameters are given in Record (n3k). VelocityDecay - Drag coefficient decreasing as roll velocity increases. Input parameters are given in Record (n3l).
wakeFraction	Influence of local flow effects on reducing flow velocity due to ship forward speed (default 0.0).
rollVelocityRatio	Influence of local flow effects on flow velocity due to ship roll (default 1.0).

### **Record (n3j), Skeg Damping Drag Coefficient**

This record is required if dragCoMethod has been set to Constant in Record (n3i).

“skegDragCo”, dragCoRef (1 character string, 1 float)

“skegDragCo”	Record tag.
dragCoRef	Drag coefficient.

### **Record (n3k), Skeg Damping Amplitude Decay Parameters**

This record is required if dragCoMethod has been set to AmplitudeDecay in Record (n3i).

“skegAmpDecay”, dragCoRef, rollAmpRefDeg, alphaDecayDragCo (1 character string, 3 floats)

“skegAmpDecay”	Record tag.
dragCoRef	Reference drag coefficient.
rollAmpRefDeg	Reference roll amplitude (deg).
alphaDecayDragCo	Reference drag decay coefficient. This value should be $\geq 0.0$ .

### **Record (n3l), Skeg Damping Velocity Decay Parameters**

This record is required if dragCoMethod has been set to VelocityDecay in Record (n3i).

“skegVelDecay”, dragCoRef, rollVelAmpRefDeg, alphaDecayDragCo

“skegVelDecay”      Record tag.

dragCoRef            Reference drag coefficient.

rollVelAmpRefDeg    Reference roll velocity amplitude (deg/s).

alphaDecayDragCo    Reference drag decay coefficient.

### **Record (n3m), End of Skeg Data**

This record must be entered at the end of data for a skeg

“end skeg” (1 character string with 2 words)

### **Record (n4), Beginning of Rudder Data**

Records (n4) to (n4) are optional, and can be repeated for each rudder or rudder pair.

“begin rudder” (1 character string with 2 words)

### **Record (n5), Pair Option**

This record must follow Record (n4).

“pairOption”, pairOption (1 character string with 2 words)

“pairOption”      Record tag.

pairOption        Option for input of single rudder or pair of rudders.

single - Input given for a single rudder.

pair - Input is used to create a pair of rudders. Input dimensions should be provided for the port rudder.

### **Record (n5a), Rudder Label**

This record must follow Record (n5).

“label” label (2 character strings)

“label”      Record tag.

label          Label for rudder. This can include spaces. If pairOption is set to pair in Record (n5), then the port and starboard rudder labels will be appended with “(port)” and “(starboard)” respectively.

### **Record (n5b), Rudder Dimensions**

This record must follow Record (n5a).

“dimen”, station, yRoot, zBlRoot, span, chordRoot, chordTip, dihedralDeg  
(1 character string, 7 floats)

“dimen”	Record tag.
station	Station of centroid.
yRoot	Lateral offset of root (m, +port).
zBlRoot	Vertical coordinate of root relative to baseline (m, +up).
span	Span (m).
chordRoot	Chord length at root (m).
chordTip	Chord length at tip (m).
dihedralDeg	Dihedral angle (deg).

### **Record (n5c), Rudder Incident Flow Coefficients**

This record is optional. If this record is not included, then default values are used.

“incFlowCo”, wakeFraction, flowStraighteningCo (1 character string, 2 floats)

“incFlowCo”	Record tag.
wakeFraction	Influence of local flow effects on reducing flow velocity due to ship forward speed (default 0.0).
flowStraighteningCo	Coefficient for reducing the incident flow velocity component normal to the rudder due to flow straightening effects. This coefficient typically has a value between 0.0 and 1.0, with a value of 1.0 indicating that the local normal flow velocity isn’t influenced by the propeller, hull, or other effects (default 1.0). For a vertical rudder (most common case), the flow straightening coefficient only influences the incident lateral flow velocity.



### Record (n5d), Rudder Lift and Drag Coefficients

This record is optional. If this record is not included, then default values are used.

“liftDragCo”, liftCoSlope, liftCoMax, dragCoSlope, dragCoNormal (1 character string, 4 floats)

“liftDragCo”	Record tag.
liftCoSlope	Lift curve slope $\partial C^{lift} / \partial \alpha$ (/rad). If this record is omitted then a default value is computed based on the foil aspect ratio.
liftCoMax	Maximum value for lift coefficient $C^{lift}$ (default 1.2).
dragCoSlope	Drag curve slope $\partial C^{drag} / \partial (\alpha^2)$ (/rad <sup>2</sup> ). If this record is omitted then a default value is computed based on the foil aspect ratio.
dragCoNormal	Drag coefficient for flow normal to the rudder surface (default 1.17).

### Record (n5e), Rudder Autopilot Parameters

This record must follow Record (n5b), (n5c), or (n5d).

“autopilotParam”, deflectMaxDeg, velMaxDeg, accMaxDeg, freqResponse, dampResponse, dtMax (1 character string, 6 floats)

“autopilotParam”	Record tag
deflectMaxDeg	Maximum rudder deflection angle (deg). This value is typically set to 35°.
velMaxDeg	Maximum rudder deflection velocity (deg/s). If this value is set to 0.0, then the maximum velocity is unlimited.
accMaxDeg	Maximum rudder acceleration (deg/s <sup>2</sup> ). If this value is set to 0.0, then the maximum acceleration is unlimited.
freqResponse	Undamped response frequency of rudder autopilot.
dampResponse	Damping of rudder autopilot as a fraction of critical damping. This value is typically between 0.5 and 1.0.
dtMax	Maximum time increment for time stepping of rudder motions. If this value is set to 0.0, then the no limit is applied and time stepping is done using the same time increment as for ship motions.

### **Record (n5f), Rudder Autopilot Displacement Gains**

This record must follow Record (n5e).

“dispGains”, surgeGain, swayGain, heaveGain, rollGain, pitchGain,  
yawGain (1 character string, 6 floats)

“dispGains”    Record tag

surgeGain      Surge gain (deg/m). This value should be 0.0.

swayGain       Sway gain (deg/m). This value should be 0.0.

heaveGain      Heave gain (deg/m). This value is typically 0.0.

rollGain       Roll gain (deg/deg). This value is typically 0.0 unless rudder roll  
stabilization is desired.

pitchGain      Pitch gain (deg/deg). This value is typically 0.0.

yawGain        Yaw gain (deg/deg). For a typical ship with a downward oriented  
rudder, this value is typically  $\leq 0.0$ .

### **Record (n5g), Rudder Autopilot Velocity Gains**

This record is optional and can follow Record (n5f). If this record is not  
included, then all velocity gains are set to 0.0.

“velGains”, surgeVelGain, swayVelGain, heaveVelGain, rollVelGain,  
pitchVelGain, yawVelGain (1 character string, 6 floats)

“velGains”      Record tag

surgeVelGain   Surge velocity gain (deg/(m/s)). This value should be 0.0.

swayVelGain    Sway velocity gain (deg/(m/s)). This value should be 0.0.

heaveVelGain   Heave velocity gain (deg/(m/s)). This value is typically 0.0.

rollVelGain    Roll velocity gain (deg/(deg/s)). This value is typically 0.0 unless  
rudder stabilization is desired.

pitchVelGain   Pitch velocity gain (deg/(deg/s)). This value is typically 0.0.

yawVelGain     Yaw velocity gain (deg/(deg/s)). For a typical ship with a  
downward oriented rudder, this value is typically  $\leq 0.0$ .

### **Record (n5h), Rudder Autopilot Integral Gains**

This record is optional and can follow Record (n5f) or (n5g). If this record is not included, then all integral gains are set to 0.0.

“intGains”, surgeIntGain, swayIntGain, heaveIntGain, rollIntGain, pitchIntGain, yawIntGain (1 character string, 6 floats)

“intGains”      Record tag

surgeIntGain    Surge integral gain (deg/(m·s)). This value should be 0.0.

swayIntGain    Sway integral gain (deg/(m·s)). This value should be 0.0.

heaveIntGain    Heave integral gain (deg/(m·s)). This value is typically 0.0.

rollIntGain    Roll integral gain (deg/(deg·s)). This value is typically 0.0 unless rudder stabilization is desired.

pitchIntGain    Pitch integral gain (deg/(deg·s)). This value is typically 0.0.

yawIntGain    Yaw integral gain (deg/(deg·s)). For a typical ship with a downward oriented rudder, this value is typically  $\leq 0.0$ .

### **Record (n5i), Rudder Autopilot Integration Time**

This record must be included after Record (n5h) if Record (n5h) is included.

“integrationTime”, integrationTime (1 character string, 1 float)

“integrationTime”      Record tag.

integrationTime      Integration time for rudder autopilot (s).

### **Record (n5j), End of Rudder Data**

This record must follow Record (n5f) or (n5g).

“end rudder”(1 character string with 2 words)

### **Record (n6), End of Appendage Data**

“end appendages”(1 character string with 2 words)

### **Record (o), Beginning of Propeller Data**

“begin propellers”(1 character string with 2 words)

### **Record (o1), Beginning of Fixed Pitch Propeller**

This record is optional, and must follow Record (o). Sequences of Records (o1) to (o2g) can be entered to described an arbitrary number of fixed pitch propellers.

“begin fixedPitchPropeller” (1 character string with 2 words)

**Note:** If the shipType in Record (c) is set to steadyFD, then input propellers will not be used for computations and will not be plotted as part of the ship.

### **Record (o2), Pair Option**

This record must follow Record (o1).

“pairOption”, pairOption (1 character string with 2 words)

“pairOption” Record tag.

pairOption Option for input of single propeller or pair of propellers.

single - Input given for a single propeller.

pair - Input is used to create a pair of propellers. Input dimensions should be provided for the port propeller.

### **Record (o2a), Fixed Pitch Propeller Label**

This record must follow Record (o2).

“label” label (2 character strings)

“label” Record tag.

label Label for fixed pitch propeller. This can include spaces. If pairOption is set to pair in Record (o2), then the port and starboard propeller labels will be appended with “(port)” and “(starboard)” respectively.

### **Record (o2b), Fixed Pitch Propeller Dimensions**

This record must follow Record (o2a).

“dimen”, station, y, zBl, diameter (1 character string, 4 floats)

“dimen” Record tag.

station Station.

y Lateral offset of centre (m, +port).

zBl Vertical coordinate of centre relative to baseline (m, +up).

diameter Diameter (m).

### Record (o2c), Fixed Pitch Propeller Hydrodynamic Coefficients

This record must follow Record (o2b).

“propCo”, wakeFraction, thrustDeduction, (1 character string, 2 floats)

“propCo”                      Record tag.

wakeFraction                Wake fraction coefficient.

thrustDeduction            Thrust deduction coefficient.

### Record (o2d), Fixed Pitch Propeller Thrust Coefficient Quadratic Equation Terms

Either this record or Record (o2e) must follow Record (o2c).

“thrustCoQuadratic”, kt0, ktj1, ktj2 (1 character string, 3 floats)

“thrustCoQuadratic”      Record tag.

kt0                            Thrust coefficient constant term.

ktj1                          Thrust coefficient linear term.

ktj2                          Thrust coefficient quadratic term.

**Note:**                      The thrust coefficient is evaluated by:  
$$K_T = kt0 + ktj1 J_{prop} + ktj2 J_{prop}^2$$
  
where  $J_{prop}$  is the propeller advance coefficient.

### Record (o2e), Fixed Pitch Propeller Input Thrust Coefficients

Either this record or Record (o2d) must follow Record (o2c).

“thrustCoInput”, j1, kt1, j2, kt2, j3, kt3 (1 character string, 6 floats)

“thrustCoInput”          Record tag.

j1                              First advance coefficient.

kt1                            Thrust coefficient for advance coefficient j1.

j2                              Second advance coefficient.

kt2                            Thrust coefficient for advance coefficient j2.

j3                              Third advance coefficient.

kt3                            Thrust coefficient for advance coefficient j3.

**Note:**                      The thrust coefficient is evaluated by:  
$$K_T = kt0 + ktj1 J_{prop} + ktj2 J_{prop}^2$$
  
where  $J_{prop}$  is the propeller advance coefficient. The coefficients kt0, ktj1, and ktj2 are evaluated by matching the input values given in this record.

### **Record (o2f), Fixed Pitch Propeller Controller Parameters**

This record must follow Record (o2d) or (o2e).

“propControlParam”, rpmMin, rpmMax, speedGain, accGain,  
freqResponseRpm, dampResponseRpm, rpmVelMax, rpmAccMax, dtMax  
(1 character string, 9 floats)

“propControlParam”	Record tag
rpmMin	Minimum rudder RPM
rpmMax	Maximum rudder RPM
speedGain	gain for ship forward speed (RPM/(m/s)
accGain	gain for ship forward speed acceleration (RPM/(m/s <sup>2</sup> ).
freqResponseRpm	Undamped response frequency of propeller controller (rad/s).
dampResponseRpm	Damping of propeller controller as a fraction of critical damping.
rpmVelMax	Maximum rate of change of propeller RPM (RPM/s). If this value is set to 0.0, then the maximum rate of change unlimited.
rpmAccMax	Maximum second derivative of RPM with respect to time (RPM/s <sup>2</sup> ). If this value is set to 0.0, then no limit is applied.
dtMax	Maximum time increment for time stepping of propeller RPM. If this value is set to 0.0, then time stepping is done using the same time increment as for ship motions.

### **Record (o2g), End of Data for Fixed Pitch Propeller**

This record must follow Record (o2f).

“end fixedPitchPropeller”(1 character string with 2 words)

### **Record (o3), End of Data for Propellers**

“end propellers”(1 character string with 2 words)

### **Record (p), Beginning of Rudder-Propeller Interaction Coefficients**

“begin rudderPropCo”(1 character string with 2 words)

### **Record (p1), Rudder-Propeller Interaction Coefficients**

There must be nRudder Records (p1), where nRudder is the number of rudders described by Records (n4) to (n5j).

“rudderPropCo”, indexRudder, rudderPropCos for rudder indexRudder (1 character string, 1 integer, nPropeller floats)

“rudderPropCo”    Record tag

indexRudder        Rudder index for Record. Rudder indexes for successive Records (p1) must increase from 0 to nRudder-1.

rudderPropCos      Rudder-prop interaction coefficients for rudder indexRudder. The number of values must correspond with the number of propellers described by Records (o1) to (o2g).

**Note:**            If any appendages or propellers are created with pairOption set to pair, then the port object is created first, followed by the starboard object. This convention should be considered when specifying input rudder-propeller interaction coefficients.

### **Record (p2), End of Rudder-Propeller Interaction Coefficients**

“end rudderPropCo” (1 character string with 2 words)

### **Record (q), Ship Plot Output Option**

This record is optional.

(2 character strings)

“shipPlotOutOption”    Record tag.

shipPlotOutOption      Option for making plots of the ship hull and appendages.  
screen - Plots are only plotted on the screen (default).  
screenFile - Plots are both plotted on the screen and to a file.  
file - Plots are only written to a file.

### **Record (r), Beginning of Ship Plot Data**

This record is optional.

“begin shipPlots” (1 character string with 2 words)

**Note:**    If this record is entered, then it can be followed by an arbitrary number of repetitions of Records (r1) to (r6) giving plot parameters. Record (r7) must follow at the end of plot parameter data.

### **Record (r1), Ship Plot Options**

This record is required if a plot is being specified.

“shipPlotOptions”, fileFormatShip, starboardOption, smoothShadeOption,  
(4 character strings)

“shipPlotOptions”	Record tag.
fileFormatShip	Ship plot format. Available formats are bmp, eps, gif, pdf, png, ppm, ps, svg, tiff, and wmf.
colourTable	Colour table. Available tables are small, vga, rain, spec, grey, rrain, rspec, rgrey, temp, partialGrey, wetWhiteDryGrey, white, redHullYellowApp, and hullAppProp.
starboardOption	Option for plotting starboard portion of hull. noStarboard - Only the port side of hull is plotted. includeStarboard - Both starboard and port sides of hull are plotted.
smoothShadeOption	Option for shading of hull panels. nonSmooth - Each panel has a constant colour based on the centroid location. smooth - Each panel can have colour variation within the panel.

### **Record (r2), Ship Plot File Name**

This record is required if a plot is being specified.

“shipPlotFileName”, shipPlotFileName (2 character strings)

“shipPlotFileName”	Record tag.
shipPlotFileName	Name of output ship plot file.

### **Record (r3), View Point**

This record is required if a plot is being specified.

“viewPoint”, xView, yView, zWView (1 character string, 3 floats)

“viewPoint”	Record tag.
xView	$x$ coordinate of view point relative to ship LCG.
yView	$y$ coordinate of view point relative to ship centreline.
zWView	$z$ coordinate of view point relative to calm waterline



#### **Record (r4), Zoom Factor**

This record is optional if a plot is being specified.

“zoomFactor”, zoomFactor (1 character string, 1 float)

“zoomFactor” Record tag.

zoomFactor Plot zoom factor. For a zoom factor of 1.0, the program attempts to fill the view area with the plot.

**Note:** If this record is omitted for a plot, then a default of 1.0 is used.

#### **Record (r5), Ship Image Size**

This record is optional if a ship plot is being specified.

“imageSizeShip”, widthmmShip, heightmmShip (1 character string, 2 floats)

“imageSizeShip” Record tag.

widthmmShip Plot width (mm). (Default 150 mm)

heightmmShip Plot height (mm). (Default 100 mm)

**Note:** If this record is omitted for a plot, then the default values are used.

#### **Record (r6), Stations for Cropping Plot**

This record is optional if a plot is being specified.

“cropStations”, stationMinCrop, stationMaxCrop (1 character string, 2 floats)

“cropStations” Record tag.

stationMinCrop Minimum station for cropping plot.

stationMaxCrop Maximum station for cropping plot.

**Note:** If this record is omitted for a plot, then there is no cropping of the plot.

#### **Record (r7), End of Ship Plot Data**

“end shipPlots” (1 character string with 2 words)

### **Record (s), Retardation Function Plot Option**

“retardPlotOption”, retardPlotOption (2 character strings)

“retardPlotOption” Record tag.

retardPlotOption Option for making plots of hydrodynamic retardation coefficients.

noPlots - No plots are produced.

screenFile - Plots are both plotted on the screen and to a file.

screen - Plots are only plotted on the screen.

file - Plots are only written to a file.

### **Record (s1), Retardation Plot File Name Prefix**

This record is optional. If the record is omitted, then no prefix is used.

“retardPlotNamePrefix”, retardPlotNamePrefix (2 character strings)

“retardPlotNamePrefix” Record tag.

retardPlotNamePrefix Prefix for retardation function plot files (default is no prefix).

### **Record (s2), Retardation Function Plot File Format**

This record is optional. If the record is omitted, then png format is used.

“fileFormatRetard”, fileFormatRetard (2 character strings)

“fileFormatRetard” Record tag.

fileFormatRetard Plot format. Available formats are bmp, eps, gif, pdf, png, ppm, ps, svg, tiff, and wmf.

### **Record (s3), Retardation Function Plot Image Size**

This record is optional

“plotSize”, widthmmRetard, heightmmRetard (1 character string, 1 float)

“plotSize” Record tag.

widthmmRetard Plot width (mm). (Default 120 mm)

heightmmRetard Plot height (mm). (Default 80 mm)

**Note:** If this record is omitted, then the default values are used.

### **Record (t), Evaluation of Propeller RPM for Ship Speed Option**

“rpmSpeedOption”, rpmSpeedOption (2 character strings)	
“rpmSpeedOption”	Record tag.
rpmSpeedOption	Option for computing propeller RPM for specified ship speeds. rpmSpeed - Required propeller RPMs are evaluated for specified ship speeds. noRpmSpeed - Propeller RPMs are not evaluated for ship speeds.
<b>Note:</b>	Propeller RPMs for ship speeds are evaluated only if option shipType in Record (c) is set to freeTD.

### **Record (t1), Parameters for Computing Ship RPM Given Speed**

This record is required if rpmSpeedOption is set to rpmSpeed in Record (t)	
“paramRpmSpeed”, nPropRpm, rpmMax, dtMaxRpm, tEndRpm (1 character string, 1 integer, 3 floats)	
“paramRpmSpeed”	Record tag.
nPropRpm	Number of propellers that are rotating when determining propeller RPM for given speed.
rpmMax	Maximum propeller RPM.
dtMaxRpm	Time step size (s) for simulation of motions. A value of 0.2 s is recommended for full-scale ships.
tEndRpm	End time for simulation of motions to determine final ship speed. A value of 300 s is recommended for full-scale ships.

### **Record (t2), Propeller Indices for Computing Ship RPM Given Speed**

This record is required if rpmSpeedOption is set to rpmSpeed in Record (t)	
“indicesPropRpm”, indicesPropRpm (1 character string, nPropRpm integers)	
“indicesPropRpm”	Record tag.
indicesPropRpm	Indices of propellers that are rotating when determining ship speed. Each index must be in the range between 0 and nProp–1.

**Record (u1), Ship Speeds in m/s for Determining RPM**

This record or Record (u2) is required if rpmSpeedOption is set to rpmSpeed in Record (t)

“speedsRpm”, speedsRpm (1 character string, array of floats)

“speedsRpm” Record tag.

speedsRpm Array of ship speeds (m/s) at which propeller RPM values are determined.

**Record (u2), Ship Speeds in Knots for Determining RPM**

This record or Record (u1) is required if rpmSpeedOption is set to rpmSpeed in Record (t)

“speedsKnotsRpm”, speedsKnotsRpm (1 character string, array of floats)

“speedsKnotsRpm” Record tag.

speedsKnotsRpm Array of ship speeds (knots) at which propeller RPM values are determined.

**Record (v), End of Ship Data**

“end SM3DBuildShip”(1 character string with 2 words)

## C.2 Sample Input File for SM3DBuildShip

```
begin SM3DBuildShip
label Generic frigate
shipType freeTD
radDifDBFileName genFrigRadDifDB.pkl
shipDBFileName genFrigFreeShip.pkl
dryPanelOption dryPanel
dryPanelFileName genFrigDryPanelHull.pkl
loadCondition 1025.0 4.2 0.0 6.0
correctionGM 0.0
gyradii 4.8 30.0 30.0
tRetardIncMax 0.1 20.0
enFreqIntIncMax 0.1 6.0
begin hullViscous
    speedsResistKnots 5.0 10.0 15.0 20.0 25.0 30.0 35.0
    resistOption HoltropMennen
    hullDragCo 1.17 0.0
end hullViscous
begin hullManeuver
    hullManMethod Inoue
end hullManeuver
begin appendages
    begin bilgeKeel
        pairOption pair
        label Bilge keel
        stations      6      7      8      9      10     11     12     13     14
        yRoots        5.14 5.57 5.80 5.83 5.97 5.91 5.80 5.58 5.23
        zBlRoots      2.49 2.21 1.94 1.66 1.66 1.66 1.66 1.66 1.66
        spans         0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
        dihedralsDeg -45  -45  -45  -45  -45  -45  -45  -45  -45
    end bilgeKeel
    begin foil
        pairOption pair
        label Outer shaft bracket
        dimen 18.0 4.0 3.04 3.0 1.0 1.0 -105.0
    end foil
    begin foil
        pairOption pair
        label Inner shaft bracket
        dimen 18.0 0.5 2.5 3.2 1.0 1.0 -45.0
    end foil
    begin skeg
        pairOption single
        label Skeg
```

```

        stations      14.0  16.0
        yRoots        0.0   0.0
        zBlRoots      0.    0.276
        spans         0.0   1.2
        dihedralsDeg -90.0 -90.0
    end skeg
    begin rudder
        pairOption single
        label Rudder
        dimen 19.0 0.0 3.6 4.8 4.8 2.4 -90.0
        autopilotParam 35.0 3.0 0.0 3.0 0.85 0.1
        dispGains 0.0 0.0 0.0 0.0 0.0 -4.0
        velGains 0.0 0.0 0.0 0.0 0.0 -8.0
    end rudder
end appendages
begin propellers
    begin fixedPitchPropeller
        pairOption pair
        label Propeller
        dimen 18.5 2.9 0.2 4.0
        propCo 0.0 0.0
        thrustCoQuadratic 0.4 -0.20 -0.16
        propControlParam 0.0 300 -5.0 -1.0 3.0 0.8 50.0 0.0 0.1
    end fixedPitchPropeller
end propellers
begin rudderPropCo
    rudderPropCo 0 0.5 0.5
end rudderPropCo
shipPlotOutOption screen
begin shipPlots
    shipPlotOptions png hullAppProp includeStarboard nonSmooth
    shipPlotFileName shipAftLowerView.png
    viewPoint -120.0 120.0 -60.0
    zoomFactor 1.5
    imageSizeShip 150.0 100.0
    cropStations -1.0e6 1.0e6
    shipPlotOptions png hullAppProp includeStarboard nonSmooth
    shipPlotFileName shipAftView.png
    viewPoint -120.0 0.0 0.0
    zoomFactor 1.0
    imageSizeShip 150.0 100.0
    cropStations -1.0e6 1.0e6
end shipPlots
retardPlotOption screen
rpmSpeedOption rpmSpeed

```

```
paramRpmSpeed 2 300.0 0.2 300.0
indicesPropRpm 0 1
speedsKnotsRpm 5.0 10.0 15.0 20.0 25.0 30.0
end SM3DBuildShip
```

### C.3 Sample Output File for SM3DBuildShip

Program SM3DBuildShip

ShipMo3D library Version 1.0c - 26 November 2007

Time : Wed Feb 06 15:24:49 2008

Run label:

Generic frigate

\*\*\*\* ECHO OF USER INPUT \*\*\*\*

Ship type : freeTD

Input radiation and diffraction database file name:

genFrigRadDifDB.pkl

Output ship database file name:

genFrigFreeShip.pkl

Dry panel hull option : dryPanel

Input hull dry panel file name:

genFrigDryPanelHull.pkl

Water density : 1025.000 kg/m3

Draft of baseline at midships : 4.200 m

Trim of baseline by stern : 0.000 m

Height of CG above baseline, KG : 6.000 m

Correction to metacentric height : 0.000 m

Ship gyradii

Roll gyradius : 4.800 m

Pitch gyradius : 30.000 m

Yaw gyradius : 30.000 m

Time parameters for hull retardation forces

Time interval : 0.100 s

Maximum time : 20.000 s

Encounter frequency parameters for integration of hull retardation functions

Encounter frequency increment : 0.100 rad/s

Maximum encounter frequency : 6.000 rad/s

\*\* Viscous hull input

Ship speeds for resistance (knots)

5.000 10.000 15.000 20.000 25.000 30.000 35.000

Ship resistance option: HoltropMennen



Resistance coefficients based on Holtrop and Mennen

Hull geometry for resistance calculations based on wet panel hull  
No bulbous bow

User input hull lateral and roll eddy drag coefficients

Eddy-making roll damping coefficient : 1.170

Lateral drag coefficient : 0.000

\*\* Hull maneuvering coefficient input

Hull dimensions for evaluating maneuvering coefficients

Dimensions based on baseline wet panelled hull

Draft at midships : 4.200 m

Trim by stern : 0.000 m

Maximum beam : 14.115 m

Block coefficient : 0.510

Maneuvering force elevation wrt waterline : 0.000 m

Hull maneuvering coefficients based on Inoue

Hull maneuvering coefficients

Sway-sway yv : -0.193884

Sway-yaw yr : 0.054978

Yaw-sway nv : -0.070000

Yaw-yaw nr : -0.032900

Nonlinear sway-sway yvv : -0.858375

Nonlinear sway-sway yvr : -0.180291

Nonlinear sway-yaw yrr : 0.000000

Nonlinear yaw-sway nvr2 : 0.000000

Nonlinear yaw-yaw nrr : -0.060000

Nonlinear yaw-yaw nrv2 : -0.200000

\*\* Appendage input

Input for bilge keel pair, dimensions given for port bilge keel

Label : Bilge keel

Station	yRoot (m)	zBlRoot (m)	span (m)	dihedral angle (deg)	
6.000		5.140	2.490	0.600	-45.000
7.000		5.570	2.210	0.600	-45.000
8.000		5.800	1.940	0.600	-45.000
9.000		5.830	1.660	0.600	-45.000
10.000		5.970	1.660	0.600	-45.000
11.000		5.910	1.660	0.600	-45.000
12.000		5.800	1.660	0.600	-45.000
13.000		5.580	1.660	0.600	-45.000

14.000      5.230      1.660      0.600      -45.000  
 Added mass option : includeAddedMass (default)  
 Drag coefficient method : Ikeda (default)  
 Wake fraction : 0.000 (default)  
 Roll velocity ratio : 1.000 (default)

Input for static foil pair, dimensions given for port foil

Label : Outer shaft bracket

Station : 18.000  
 Y of root : 4.000 m  
 Z root above baseline : 3.040 m  
 Span : 3.000 m  
 Chord at root : 1.000 m  
 Chord at tip : 1.000 m  
 Dihedral angle : -105.000 deg  
 Hydrodynamic parameters  
 Added mass option : includeAddedMass (default)  
 Wake fraction : 0.000 (default)  
 Lift coefficient slope : 4.176 /rad (default)  
 Drag coefficient for normal flow : 1.170 (default)

Input for static foil pair, dimensions given for port foil

Label : Inner shaft bracket

Station : 18.000  
 Y of root : 0.500 m  
 Z root above baseline : 2.500 m  
 Span : 3.200 m  
 Chord at root : 1.000 m  
 Chord at tip : 1.000 m  
 Dihedral angle : -45.000 deg  
 Hydrodynamic parameters  
 Added mass option : includeAddedMass (default)  
 Wake fraction : 0.000 (default)  
 Lift coefficient slope : 4.255 /rad (default)  
 Drag coefficient for normal flow : 1.170 (default)

Input for skeg

Label : Skeg

Station	yRoot (m)	zBlRoot (m)	span (m)	dihedral angle (deg)
14.000	0.000	0.000	0.000	-90.000
16.000	0.000	0.276	1.200	-90.000

Added mass option : includeAddedMass (default)  
 Drag coefficient method : Ikeda (input)  
 Wake fraction : 0.000 (input)

Roll velocity ratio : 1.000 (input)

Input for rudder

Label : Rudder

Station : 19.000

Y of root : 0.000 m

Z root above baseline : 3.600 m

Span : 4.800 m

Chord at root : 4.800 m

Chord at tip : 2.400 m

Dihedral angle : -90.000 deg

Hydrodynamic parameters

Wake fraction : 0.000

Flow straightening coefficient : 1.000

Lift coefficient slope : 2.938 /rad (default)

Maximum lift coefficient : 1.200 (default)

Drag coefficient slope : 1.030 /rad\*\*2 (default)

Drag coefficient for normal flow : 1.170 (default)

Autopilot parameters

Maximum deflection : 35.000 deg

Maximum deflection velocity : 3.000 deg/s

Maximum deflection acceleration : 0.000 deg/s

Response frequency : 3.000 rad/s

Response damping : 0.850 (fraction of critical)

Maximum time step : 0.100000 s

Autopilot displacement gains

Surge : 0.000 deg/m

Sway : 0.000 deg/m

Heave : 0.000 deg/m

Roll : 0.000 deg/deg

Pitch : 0.000 deg/deg

Yaw : -4.000 deg/deg

Autopilot velocity gains (input)

Surge : 0.000 deg/(m/s)

Sway : 0.000 deg/(m/s)

Heave : 0.000 deg/(m/s)

Roll : 0.000 deg/(deg/s)

Pitch : 0.000 deg/(deg/s)

Yaw : -8.000 deg/(deg/s)

Autopilot integral gains (default)

Surge : 0.000 deg/(m\*s)

Sway : 0.000 deg/(m\*s)

Heave : 0.000 deg/(m\*s)

Roll : 0.000 deg/(deg\*s)

Pitch : 0.000 deg/(deg\*s)

Yaw : 0.000 deg/(deg\*s)  
Autopilot integration time : 0.000 s (default)

End of appendage input

Rudder indices and labels

Index	Label
0	Rudder

\*\* Propeller input

Input for fixed pitch propeller pair, dimensions given for port prop

Label : Propeller

Propeller dimensions : 18.500  
Station : 18.500  
Y of centre : 2.900 m  
Z of centre above baseline : 0.200 m  
Diameter : 4.000 m

Hydrodynamic characteristics

Wake fraction : 0.000  
Thrust deduction coefficient : 0.000

Input thrust quadratic coefficients given as input

Thrust coefficient  $kt_0$  : 0.400  
Thrust coefficient  $kt_{j1}$  : -0.200  
Thrust coefficient  $kt_{j2}$  : -0.160

Thrust coefficient  $K_t = kt_0 + kt_{j1} * J_{advance} + kt_{j2} * J_{advance}^2$

Propeller controller parameters

Minimum RPM : 0.000 deg  
Maximum RPM : 300.000 deg  
Speed gain : -5.000 RPM/(m/s)  
Acceleration gain : -1.000 RPM/(m/s\*\*2)  
Response frequency : 3.000 rad/s  
Response damping : 0.800 (fraction of critical)  
Maximum dRPM/dt : 50.000 RPM/s  
Maximum d2RPM/dt2 : 0.000 RPM/s\*\*2  
Maximum time step : 0.100000 s

End of propeller input

Propeller indices and labels

Index	Label
0	Propeller (port)
1	Propeller (starboard)

\*\* Rudder-propeller interaction coefficients

Rudder index	Interaction coefficients	
0	0.500	0.500

Ship plot option : screen (input)

Ship plot parameters

File format : png  
 Colour table : hullAppProp  
 Starboard option : includeStarboard  
 Smooth shade option : nonSmooth  
 Ship plot file name : shipAftLowerView.png  
 View point location : -120.000 120.000 -60.000  
 Zoom factor : 1.500 (input)  
 Image width and height (mm) : 150.0 100.0 (input)  
 Stations for cropping image: -1000000.000 1000000.000

Ship plot parameters

File format : png  
 Colour table : hullAppProp  
 Starboard option : includeStarboard  
 Smooth shade option : nonSmooth  
 Ship plot file name : shipAftView.png  
 View point location : -120.000 0.000 0.000  
 Zoom factor : 1.000 (input)  
 Image width and height (mm) : 150.0 100.0 (input)  
 Stations for cropping image: -1000000.000 1000000.000

Retardation function plot option : screen

No prefix to retardation function plot file names

Retardation function plot file format : png

Retardation function plot width : 120 mm

Retardation function plot height : 80 mm

Option for computing RPMs from specified speeds : rpmSpeed

Number of propellers for determining RPM : 2

Maximum allowable RPM : 300.000

Time step for simulating ship speed : 0.200

End time for simulating ship speed : 300.000

Indices of propellers for determining RPM: 0 1

Ship speeds for computing RPM, (knots)

5.000	10.000	15.000	20.000	25.000	30.000
-------	--------	--------	--------	--------	--------

\*\*\*\* HULL RADIATION AND DIFFRACTION DATABASE PROPERTIES \*\*\*\*

Summary of data for hull radiation and diffraction computations

Label : Generic frigate

Water density : 1025.000 kg/m3

Encounter frequencies (rad/s)

0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800
0.900	1.000	1.100	1.200	1.300	1.400	1.500	1.600
1.700	1.800	1.900	2.000	2.100	2.200	2.400	2.500
2.600	2.700	2.800	2.900	3.000	3.100	3.200	3.300
3.400	3.500	3.600	3.700	3.800	4.000	4.400	4.500
4.700	4.800	4.900	5.000	5.100	5.200	5.300	5.400
5.500	5.600	5.700	5.800	5.900	6.000		

Ship speeds (m/s)

0.000	2.575	5.150	7.725	10.300	12.875	15.450	18.025
20.600							

Relative sea headings (deg)

0.000	15.000	30.000	45.000	60.000	75.000	90.000	105.000
120.000	135.000	150.000	165.000	180.000			

Relative wave frequencies (rad/s)

0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800
0.900	1.000	1.100	1.200	1.300	1.400	1.500	1.600
1.700	1.800	1.900	2.000				

\*\*\*\* SHIP RESISTANCE BASED ON HOLTROP, 1984 \*\*\*\*

Ship resistance non-dimensionalized by  $0.5 \cdot \rho \cdot A_w \cdot U^2$

$\rho$  = water density 1025.000 kg/m3

$A_w$  = hull wetted surface area 1754.193 m2

$U$  = ship forward speed (m/s)

Speed (m/s)	Speed (knots)	Resistance (kN)	Non-dimensional resistance
2.575	5.000	20.121	0.003375
5.150	10.000	73.568	0.003085
7.725	15.000	173.212	0.003229
10.300	20.000	359.509	0.003769
12.875	25.000	644.036	0.004322
15.450	30.000	1090.800	0.005083
18.025	35.000	1913.647	0.006551

\*\*\*\*\* OUTPUT OF BUILT SHIP PROPERTIES \*\*\*\*\*

## Load Condition Properties for Trimmed Ship

### Summary of hydrostatic properties

Number of panels on port side	:	624
Length between perpendiculars	:	120.000 m
Draft of baseline at midships	:	4.200 m
Trim of baseline by stern	:	0.000 m
Beam based on maximum y value	:	14.115 m
Volume	:	3625.687 m3
Water density	:	1025.000 kg/m3
Mass	:	3716329.367494 kg
LCB of aft of FP (m)	:	61.739 m
X origin aft of FP (m)	:	61.739 m
X value of LCB	:	0.000 m
Center of buoyancy wrt waterline	:	-1.620 m
Wetted surface area	:	1754.193 m2
Waterplane area	:	1344.547 m2
X value of center of floatation	:	-5.016 m
Integral of waterplane area*X**2	:	1235150.552 m4
Integral of waterplane area*Y**2	:	17543.034 m4
KG, height of CG above baseline	:	6.000 m
Height of CG above waterline	:	1.800 m
Metacentric height from hydrostatics	:	1.418 m

### Inertial Properties

Inertia matrix, units of kg, kg\*m, and kg\*m2

3716329.4	0.0	0.0	0.0	0.0	0.0
0.0	3716329.4	0.0	0.0	0.0	0.0
0.0	0.0	3716329.4	0.0	0.0	0.0
0.0	0.0	0.0	85624228.6	0.0	0.0
0.0	0.0	0.0	0.0	3344696430.7	0.0
0.0	0.0	0.0	0.0	0.0	3344696430.7

Roll radius of gyration	:	4.800 m
Pitch radius of gyration	:	30.000 m
Yaw radius of gyration	:	30.000 m

### Roll Metacentric Height Properties

Correction to roll metacentric height	:	0.000 m
Corrected metacentric height	:	1.418 m

### Roll Properties at Zero Forward Speed

Roll added mass : 19364305.058549 kg\*m\*\*2  
 Nondimensional roll added mass A44/I44 : 0.226  
 Natural roll frequency : 0.702 rad/s  
 Natural roll period : 8.956 s

\*\*\*\* PROPELLER RPM FOR SPECIFIED SHIP SPEEDS \*\*\*\*

Indices of active propellers :			0	1
Speed (m/s)	Speed (knots)	RPM		
2.575	5.000	41.829		
5.150	10.000	82.729		
7.725	15.000	124.784		
10.300	20.000	169.794		
12.875	25.000	216.492		
15.450	30.000	266.616		
16.923	32.859	300.000		



# Annex D: Files for Building a Seaway with SM3DBuildSeaway

---

## D.1 Format of Input Seaway File for SM3DBuildSeaway

### Record (a), Beginning Record

“begin SM3DBuildSeaway2” (1 character string with 2 words)

### Record (b), Run Label

“label”, label (2 character strings)

“label” Record tag.

label Label for run. This can include spaces.

### Record (c), Output Seaway File Name

“seawayFileName”, seawayFileName (2 character strings)

“seawayFileName” Record tag.

seawayFileName Name of output seaway file in Python pickle format.

### Record (d), Water Density

“waterDensity”, waterDensity (1 character string, 1 float)

“waterDensity” Record tag.

waterDensity Water density ( $\text{kg/m}^3$ ).

### Record (e), Time Series Sampling Parameters

This record is optional. If this record is omitted then default values are used.

“sampleParams”, tDuration, tInterval (1 character string, 2 floats)

“sampleParams” Record tag.

tDuration Duration of seaway for sample statistics (default 3600.0 s).

tInterval Time interval for sample statistics (default 0.1 s).

### **Record (f), Seaway Type**

“seawayType”, seawayType (2 character strings)

“seawayType”    Record tag.

seawayType      Type of seaway.

                  regular - Regular waves.

                  uniSpectrum - Unidirectional seaway based on input spectrum.

                  biSpectrum - Bidirectional seaway based on 2 unidirectional input spectra.

                  dirSpectrum - Directional seaway based on input spectrum.

                  componentRandom - Seaway consisting of multiple input wave components, most commonly used to represent a random seaway. Wave component phases are randomly generated.

                  componentPhase - Seaway consisting of multiple input wave components, including wave component phases.

### **Record (g), Beginning of Regular Seaway**

Records (g) to (g2) are required if seawayType is set to regular in Record (f).

“begin regularSeaway” (1 character string with 2 words)

### **Record (g1), Regular Seaway Parameters**

This record is required if seawayType in Record (f) is set to regular.

“regularParam”, waveHeadingDeg, waveFreq, waveAmp, phaseDeg, (1 character string, 4 floats

“regularParam”    Record tag.

waveHeadingDeg    Wave direction (from, degrees). 0° for waves from north, and 90° for waves from east.

waveFreq            Incident wave frequency (rad/s).

waveAmp            Incident wave amplitude (m).

phaseDeg            Phase of wave crest at  $x^f = 0.0, y^f = 0.0$  (degrees).

### **Record (g1a), Regular Seaway Nonlinear Option**

This record can optionally be used if seawayType in Record (f) is set to regular. If this record is not used, then Wheeler stretching is used.

“regNonlinearOption”, regNonlinearOption (2 character strings)

“regNonlinearOption”    Record tag.

regNonlinearOption    Option for modelling wave nonlinearities:  
Wheeler - Waves are modelled using Wheeler stretching  
(default).  
linear - Waves are modelled using linear theory.  
StokesSecond - Waves are modelled using Stokes  
second-order theory.

### **Record (g2), End of Regular Seaway**

This record is required if seawayType in Record (f) is set to regular.

“end regularSeaway” (1 character string with 2 words)

### **Record (h), Beginning of Unidirectional Seaway from Input Spectrum**

Records (h) to (h6) are required if seawayType is set to uniSpectrum in Record (f).

“begin uniSpectrumSeaway” (1 character string with 2 words)

### **Record (h1), Wave Frequency Range**

One of Records (h1) or (h2) is required if seawayType in Record (f) is set to uniSpectrum.

“uniWaveFreqRange”, waveFreqMin, waveFreqMax, waveFreqInc, randomIncOption, incSeedX, incSeedY (1 character string, 3 floats, 1 character sting, 2 integers)

“uniWaveFreqRange” Record tag.

waveFreqMin Minimum wave frequency (rad/s).

waveFreqMax Maximum wave frequency (rad/s).

waveFreqInc Wave frequency increment (rad/s).

randomIncOption Option for random wave frequency increment:  
randomInc - Intermediate wave frequencies (i.e., those other than the minimum and maximum) are randomly adjusted, with rounding to 3 decimal places. This option is useful for avoiding periodic repetition of simulated seaways.

uniformInc - The wave frequency increment between components is always waveFreqInc.

incSeedX First integer seed number for adjusting wave frequencies if randomIncOption is set to randomInc.

incSeedY Second integer seed number for adjusting wave frequencies if randomIncOption is set to randomInc.

### **Record (h2), Wave Frequencies**

One of Records (h1) or (h2) is required if seawayType in Record (f) is set to uniSpectrum

“uniWaveFreqs”, waveFreqs (1 character string, array of floats)

“uniWaveFreqs” Record tag.

waveFreqs Array of increasing wave frequencies (rad/s)

### **Record (h3), Wave Phase Seed Numbers**

This records can be optionally used if seawayType in Record (f) is set to uniSpectrum. If this record is omitted, then defaults will be used.

“uniPhaseSeeds”, phaseSeedX, phaseSeedY (1 character string, 2 integers)

“uniPhaseSeeds” Record tag.

phaseSeedX Integer seed number (default 1001).

phaseSeedY Integer seed number (default 1009).

#### **Record (h4), Relative Wave Energy Threshold**

This record can be optionally used if seawayType in Record (f) is set to uniSpectrum. If this record is omitted, then a default value will be used.

“uniThreshold”, deleteRelThreshEnergy (1 character string, 1 real)

“uniThreshold”                      Record tag.  
deleteRelThreshEnergy      Threshold for fraction of wave energy of a modelled seaway component (default  $10^{-6}$ ). If the relative energy of a seaway component is below the threshold, then the component is removed. This variable is used to avoid simulating wave spectral components with negligible wave energy.

#### **Record (h5), Unidirectional Wave Spectrum Type**

This record is required if seawayType in Record (f) is set to uniSpectrum.

“uniSpectrumType”, uniSpectrumType (2 character strings)

“uniSpectrumType”      Record tag.  
uniSpectrumType          Type of unidirectional wave spectrum:  
                                 uniBretschneider - Random seaway based on Bretschneider wave spectrum.  
                                 uniJONSWAP - Random seaway based on JONSWAP wave spectrum.

#### **Record (h5a), Unidirectional Bretschneider Spectrum Seaway Parameters**

This record is required if uniSpectrumType in Record (h5) is set to uniBretschneider

“uniBretParam”, waveHeadingDeg, hs, tp (1 character string, 3 floats)

“uniBretParam”      Record tag.  
waveHeadingDeg      Principle wave direction (from, degrees).  $0^\circ$  for waves from north, and  $90^\circ$  for waves from east.  
hs                      Significant wave height (m).  
tp                      Peak wave period (s).

### **Record (h5b), Unidirectional JONSWAP Spectrum Seaway Parameters**

This record is required if uniSpectrumType in Record (h5) is set to uniJONSWAP

“uniJONSWAPParam”, waveHeadingDeg, hs, tp, peakEnhance (1 character string, 4 floats)

“uniJONSWAPParam”    Record tag.

waveHeadingDeg        Principle wave direction (from, degrees). 0° for waves from north, and 90° for waves from east.

hs                      Significant wave height (m).

tp                      Peak wave period (s).

peakEnhance           Peak enhancement factor. This factor can be set to 3.3 to match a 2 parameter JONSWAP spectrum.

### **Record (h6), End of Unidirectional Seaway from Input Spectrum**

This record is required if seawayType in Record (f) is set to uniSpectrum.

“end uniSpectrumSeaway” (1 character string with 2 words)

### **Record (i), Beginning of Bidirectional Seaway from Input Spectrum**

Records (i) to (i6) are required if seawayType is set to biSpectrum in Record (f).

“begin biSpectrumSeaway” (1 character string with 2 words)

### Record (i1), Wave Frequency Range

One of Records (i1) or (i2) is required if seawayType in Record (f) is set to biSpectrum.

“biWaveFreqRange”, waveFreqMin, waveFreqMax, waveFreqInc, randomIncOption, incSeedX, incSeedY (1 character string, 3 floats, 1 character sting, 2 integers)

“biWaveFreqRange”	Record tag.
waveFreqMin	Minimum wave frequency (rad/s).
waveFreqMax	Maximum wave frequency (rad/s).
waveFreqInc	Wave frequency increment (rad/s).
randomIncOption	Option for random wave frequency increment. randomInc - Intermediate wave frequencies (i.e., those other than the minimum and maximum) are randomly adjusted, with rounding to 3 decimal places. This option is useful for avoiding periodic repetition of simulated seaways. uniformInc - The wave frequency increment between components is always waveFreqInc.
incSeedX	First integer seed number for adjusting wave frequencies if randomIncOption is set to randomInc.
incSeedY	Second integer seed number for adjusting wave frequencies if randomIncOption is set to randomInc.

### Record (i2), Wave Frequencies

One of Records (i1) or (i2) is required if seawayType in Record (f) is set to biSpectrum

“biWaveFreqs”, waveFreqs (1 character string, array of floats)

“biWaveFreqs”	Record tag.
waveFreqs	Array of increasing wave frequencies (rad/s)

### Record (i3), Wave Phase Seed Numbers

This records can be optionally used if seawayType in Record (f) is set to biSpectrum. If this record is omitted, then defaults will be used.

“biPhaseSeeds”, phaseSeedX, phaseSeedY (1 character string, 2 integers)

“biPhaseSeeds”	Record tag.
phaseSeedX	Integer seed number (default 1001).
phaseSeedY	Integer seed number (default 1009).

#### **Record (i4), Relative Wave Energy Threshold**

This record can be optionally used if seawayType in Record (f) is set to biSpectrum. If this record is omitted, then a default value will be used.

“biThreshold”, deleteRelThreshEnergy (1 character string, 1 real)

“biThreshold”	Record tag.
deleteRelThreshEnergy	Threshold for fraction of wave energy of a modelled seaway component (default $10^{-6}$ ). If the relative energy of a seaway component is below the threshold, then the component is removed. This variable is used to avoid simulating wave spectral components with negligible wave energy.

#### **Record (i5), Bidirectional Wave Spectrum Type**

This record is required if seawayType in Record (f) is set to biSpectrum.

“biSpectrumType”, biSpectrumType (2 character strings)

“biSpectrumType”	Record tag.
biSpectrumType	Type of bidirectional wave spectrum: biBretschneider - Random seaway based on Bretschneider wave spectrum. biJONSWAP - Random seaway based on JONSWAP wave spectrum.

#### **Record (i5a), Bidirectional Bretschneider Spectrum Seaway Parameters**

This record is required if biSpectrumType in Record (h5) is set to biBretschneider

“biBretParam”, waveHeadingDeg1, hs1, tp1, waveHeadingDeg2, hs2, tp2 (1 character string, 6 floats)

“biBretParam”	Record tag.
waveHeadingDeg1	Principle wave direction of first wave system (from, degrees). 0° for waves from north, and 90° for waves from east.
hs1	Significant wave height of first wave system (m).
tp1	Peak wave period of first wave system (s).
waveHeadingDeg2	Principle wave direction of second wave system (from, degrees). 0° for waves from north, and 90° for waves from east.
hs2	Significant wave height of second wave system (m).
tp2	Peak wave period of second wave system (s).



### **Record (i5b), Bidirectional JONSWAP Spectrum Seaway Parameters**

This record is required if biSpectrumType in Record (i5) is set to biJONSWAP

“biJONSWAPParam”, waveHeadingDeg1, hs1, tp1, peakEnhance1, waveHeadingDeg2, hs2, tp2, peakEnhance2 (1 character string, 8 floats)

“biJONSWAPParam” Record tag.

waveHeadingDeg1	Principle wave direction of first wave system (from, degrees). 0° for waves from north, and 90° for waves from east.
hs1	Significant wave height of first wave system (m).
tp1	Peak wave period of first wave system (s).
peakEnhance1	Peak enhancement factor of first wave system. This factor can be set to 3.3 to match a 2 parameter JONSWAP spectrum.
waveHeadingDeg2	Principle wave direction of second wave system (from, degrees). 0° for waves from north, and 90° for waves from east.
hs2	Significant wave height of second wave system (m).
tp2	Peak wave period of second wave system (s).
peakEnhance2	Peak enhancement factor of second wave system. This factor can be set to 3.3 to match a 2 parameter JONSWAP spectrum.

### **Record (i6), End of Bidirectional Seaway from Input Spectrum**

This record is required if seawayType in Record (f) is set to biSpectrum.

“end biSpectrumSeaway” (1 character string with 2 words)

### **Record (j), Beginning of Directional Seaway from Input Spectrum**

Records (j) to (j8) are required if seawayType is set to dirSpectrum in Record (f).

“begin dirSpectrumSeaway” (1 character string with 2 words)

### Record (j1), Wave Frequency Range

One of Records (j1) or (j2) is required if seawayType in Record (f) is set to dirSpectrum.

“dirWaveFreqRange”, waveFreqMin, waveFreqMax, waveFreqInc,  
randomIncOption, incSeedX, incSeedY (1 character string, 3 floats, 1  
character sting, 2 integers)

“dirWaveFreqRange” Record tag.

waveFreqMin Minimum wave frequency (rad/s).

waveFreqMax Maximum wave frequency (rad/s).

waveFreqInc Wave frequency increment (rad/s).

randomIncOption Option for random wave frequency increment.

randomInc - Intermediate wave frequencies (i.e., those other than the minimum and maximum) are randomly adjusted, with rounding to 3 decimal places. This option is useful for avoiding periodic repetition of simulated seaways.

uniformInc - The wave frequency increment between components is always waveFreqInc.

incSeedX First integer seed number for adjusting wave frequencies if randomIncOption is set to randomInc.

incSeedY Second integer seed number for adjusting wave frequencies if randomIncOption is set to randomInc.

### Record (j2), Wave Frequencies

One of Records (j1) or (j2) is required if seawayType in Record (f) is set to dirSpectrum

“dirWaveFreqs”, waveFreqs (1 character string, array of floats

“dirWaveFreqs” Record tag.

waveFreqs Array of increasing wave frequencies (rad/s)

### **Record (j3), Wave Heading Range**

One of Records (j3) or (j4) is required if seawayType in Record (f) is set to dirSpectrum.

“dirWaveHeadingRange”, waveHeadingMinDeg, waveHeadingMaxDeg, waveHeadingIncDeg (1 character string, 3 floats)

“dirWaveHeadingRange” Record tag.

waveHeadingMinDeg Minimum wave heading (deg).

waveHeadingMaxDeg Maximum wave heading (deg).

waveHeadingIncDeg Wave heading increment (deg).

### **Record (j4), Wave Headings**

One of Records (j3) or (j4) is required if seawayType in Record (f) is set to dirSpectrum

“dirWaveHeadings”, waveHeadings (1 character string, array of floats)

“dirWaveHeadings” Record tag.

waveHeadingsDeg Array of increasing wave headings (deg).

### **Record (j5), Wave Phase Seed Numbers**

This records can be optionally used if seawayType in Record (f) is set to dirSpectrum. If this record is omitted, then defaults will be used.

“dirPhaseSeeds”, phaseSeedX, phaseSeedY (1 character string, 2 integers)

“dirPhaseSeeds” Record tag.

phaseSeedX Integer seed number (default 1001).

phaseSeedY Integer seed number (default 1009).

### **Record (j6), Relative Wave Energy Threshold**

This record can be optionally used if seawayType in Record (f) is set to dirSpectrum. If this record is omitted, then a default value will be used.

“dirThreshold”, deleteRelThreshEnergy (1 character string, 1 real

“dirThreshold” Record tag.

deleteRelThreshEnergy Threshold for fraction of wave energy of a modelled seaway component (default  $10^{-6}$ ). If the relative energy of a seaway component is below the threshold, then the component is removed. This variable is used to avoid simulating wave spectral components with negligible wave energy.

### **Record (j7), Multi-directional Wave Spectrum Type**

This record is required if seawayType in Record (f) is set to dirSpectrum.

“dirSpectrumType”, dirSpectrumType (2 character strings

“dirSpectrumType”      Record tag.

dirSpectrumType      Type of multi-directional wave spectrum:

dirBretschneider - Random seaway based on Bretschneider wave spectrum with cosine-squared spreading function.

dirJONSWAP - Random seaway based on JONSWAP wave spectrum with cosine-squared spreading function.

tenParameter - Random seaway based on ten parameter wave spectrum.

EndecoWaveBuoy - Random seaway based on directional spectrum from Endeco 956 or 1156 wave buoy.

### **Record (j7a), Multidirectional Bretschneider Spectrum Seaway Parameters**

This record is required if dirSpectrumType in Record (j7) is set to dirBretschneider

“dirBretParam”, waveHeadingMeanDeg, hs, tp, spreadAngleDeg (1 character string, 4 floats)

“dirBretschneider”      Record tag.

waveHeadingMeanDeg      Principle wave direction (from, degrees). 0° for waves from north, and 90° for waves from east.

hs      Significant wave height (m).

tp      Peak wave period (s).

spreadAngleDeg      Directional spreading angle (deg).

### **Record (j7b), Multidirectional JONSWAP Spectrum Seaway Parameters**

This record is required if dirSpectrumType in Record (j7) is set to dirJONSWAP

“dirJONSWAPParam”, waveHeadingMeanDeg, hs, tp, peakEnhance, spreadAngleDeg (1 character string, 5 floats)

“dirJONSWAP”	Record tag.
waveHeadingMeanDeg	Principle wave direction (from, degrees). 0° for waves from north, and 90° for waves from east.
hs	Significant wave height (m).
tp	Peak wave period (s).
peakEnhance	Peak enhancement factor. This factor can be set to 3.3 to match a 2 parameter JONSWAP spectrum.
spreadAngleDeg	Directional spreading angle (deg).

### **Record (j7c), Multidirectional Ten Parameter Spectrum Seaway Parameters**

This record is required if dirSpectrumType in Record (j7) is set to tenParameter

“tenParamParam”, hs1, freqPeak1, spectralShape1, waveHeadingMeanDeg1, dirSpreadExp1, hs2, freqPeak2, spectralShape2, waveHeadingMeanDeg2, dirSpreadExp2 (1 character string, 10 floats)

“tenParameter”	Record tag.
hs1	Significant wave height of wave system 1 (m).
freqPeak1	Peak wave frequency of wave system 1 (rad/s).
spectralShape1	Spectral shape factor of wave system 1 (rad/s).
waveHeadingMeanDeg1	Principle wave direction (from, degrees) of wave systems 1. 0° for waves from north, and 90° for waves from east.
dirSpreadExp1	Directional spreading exponent of wave system 1.
hs2	Significant wave height of wave system 2 (m).
freqPeak2	Peak wave frequency of wave system 2 (rad/s).
spectralShape2	Spectral shape factor of wave system 2 (rad/s).
waveHeadingMeanDeg2	Principle wave direction (from, degrees) of wave systems 2. 0° for waves from north, and 90° for waves from east.
dirSpreadExp2	Directional spreading exponent of wave system 2.

### **Record (j7d), Endeco Wave Spectrum File Name**

This record is required if dirSpectrumType in Record (j7) is set to EndecoWaveBuoy

“EndecoSpectrumFileName”, EndecoSpectrumFileName (2 character strings)

“EndecoSpectrumFileName” Record tag.

EndecoSpectrumFileName Name of ASCII file with wave spectrum from Endeco 956 or 1156 wave buoy. The file name will typically have the extension “.std”.

### **Record (j8), End of Multi-directional Seaway from Input Spectrum**

This record is required if seawayType in Record (f) is set to dirSpectrum.

“end dirSpectrumSeaway” (1 character string with 2 words)

### **Record (k), Beginning of Seaway from Input Components, Randomly Generated Phases**

Records (k) to (k3) are required if seawayType is set to componentRandom in Record (f).

“begin componentRandomSeaway” (1 character string with 2 words)

### **Record (k1), Wave Phase Seed Numbers**

This records can be optionally used if seawayType in Record (f) is set to componentRandom. If this record is omitted, then defaults will be used.

“compPhaseSeeds”, seedX, seedY (1 character string, 2 integers)

“compPhaseSeeds” Record tag.

seedX Integer seed number (default 1001).

seedY Integer seed number (default 1009).

### **Record (k2), Wave Component Properties**

This record can be repeated to describe a seaway consisting of multiple wave components.

“componentRandom”, waveHeadingDeg, waveFreq, waveAmp (1 character string, 3 floats)

“componentRandom” Record tag.

waveHeadingDeg Wave direction (from, degrees). 0° for waves from north, and 90° for waves from east.

waveFreq Incident wave frequency (rad/s).

waveAmp Incident wave amplitude (m).

### **Record (k3), End of Seaway from Input Components, Randomly Generated Phases**

This record is required if seawayType is set to componentRandom in Record (f).

“end componentRandomSeaway” (1 character string with 2 words)

### **Record (l), Beginning of Seaway from Input Components Including Phases**

Records (l) to (l2) are required if seawayType is set to componentPhase in Record (f).

“begin componentPhaseSeaway” (1 character string with 2 words)

### **Record (l1), Wave Component Properties**

This record can be repeated to describe a seaway consisting of multiple wave components.

“componentPhase”, waveHeadingDeg, waveFreq, waveAmp (1 character string, 4 floats)

“componentPhase”    Record tag.

waveHeadingDeg    Wave direction (from, degrees). 0° for waves from north, and 90° for waves from east.

waveFreq    Incident wave frequency (rad/s).

waveAmp    Incident wave amplitude (m).

phaseDeg    Phase of incident wave crest at  $x^f = 0, y^f = 0$  (deg).

### **Record (l2), End of Seaway from Input Components, Randomly Generated Phases**

This record is required if seawayType is set to componentPhase in Record (f).

“end componentPhaseSeaway” (1 character string with 2 words)

### **Record (m), Plot Output Option**

This record is optional.

(“plotOutOption”, plotOutOption (2 character strings)

“plotOutOption”    Record tag.

plotOutOption    Option for making plots:

screenFile - Plots are both plotted on the screen and to a file.

screen - Plots are only plotted on the screen.

file - Plots are only written to a file (default).

## **Record (n), Beginning of Seaway Plot Data**

This record is optional.

“begin plots” (1 character string with 2 words)

**Note:** If this record is entered, then it can be followed by an arbitrary number of repetitions of Records (n1) to (n8) giving plot parameters. Record (n9) must follow at the end of plot parameter data.

## **Record (n1), Seaway Plot Options**

This record is required if a plot is being specified.

“plotOptions”, fileFormat, colourTable, smoothShadeOption, meshOption  
(5 character strings)

“plotOptions”	Record tag.
fileFormat	Plot format. Available formats are bmp, eps, gif, pdf, png, ppm, ps, svg, tiff, and wmf.
colourTable	Colour table. Available tables are small, vga, rain, spec, grey, rrain, rspec, rgrey, temp, partialGrey, white, blueTurquoise.
smoothShadeOption	Option for shading of hull panels: nonSmooth - Each panel has a constant colour based on the centroid location. smooth - Each panel can have colour variation within the panel.
meshOption	Option for plotting the mesh: mesh - The seaway surface mesh is plotted. noMesh - No surface mesh is plotted.

## **Record (n2), Plot File Name**

This record is required if a plot is being specified.

“plotFileName”, plotFileName (2 character strings)

“plotFileName”	Record tag.
plotFileName	Name of output plot file.



### Record (n3), X Plot Range

This record is required if a plot is being specified.

“xfRange”, xfMin, xfMax, xflnc (1 character string, 3 floats)

“xfRange” Record tag.

xfMin Minimum  $x^f$  coordinate of surface mesh.

xfMax Maximum  $x^f$  coordinate of surface mesh.

xflnc Increment of  $x^f$  coordinate of surface mesh.

### Record (n4), Y Plot Range

This record is required if a plot is being specified.

“yfRange”, yfMin, yfMax, yflnc (1 character string, 3 floats)

“yfRange” Record tag.

yfMin Minimum  $y^f$  coordinate of surface mesh.

yfMax Maximum  $y^f$  coordinate of surface mesh.

yflnc Increment of  $y^f$  coordinate of surface mesh.

### Record (n5), Time of plot.

This record is optional if a plot is being specified.

“time”, time (1 character string, 1 floats)

“time” Record tag.

time Time at which sea surface is plotted (default 0.0).

**Note:** If this record is omitted for a plot, then a default of 0.0 is used.

### Record (n6), Seaway View Point

This record is required if a plot is being specified.

“viewPoint”, xfView, yfView, zWlView (1 character string, 3 floats)

“viewPoint” Record tag.

xfView  $x^f$  coordinate of view point.

yfView  $y^f$  coordinate of view point.

zWlView  $z$  coordinate of view point relative to calm waterline.

**Record (n7), Zoom Factor**

This record is optional if a plot is being specified.

“zoomFactor”, zoomFactor (1 character string, 1 float)

“zoomFactor” Record tag.

zoomFactor Plot zoom factor (default 1.0). For a zoom factor of 1.0, the program attempts to fill the view area with the plot.

**Note:** If this record is omitted for a plot, then a default of 1.0 is used.

**Record (n8), Image Size**

This record is optional if a plot is being specified.

“imageSize”, widthmm, heightmm (1 character string, 2 floats)

“imageSize” Record tag.

widthmm Plot width (mm). (Default 150 mm)

heightmm Plot height (mm). (Default 100 mm)

**Note:** If this record is omitted for a plot, then the default values are used.

**Record (n9), End of Plot Data**

“end plots” (1 character string with 2 words)

**Record (o), End of Seaway**

“end SM3DBuildSeaway”(1 character string with 2 words)

## D.2 Sample Input File for SM3DBuildSeaway

```
begin SM3DBuildSeaway
label Hs = 3.25 m, Tp = 9.7 s, Bretschneider spectrum
seawayFileName bretSeaState5.pkl
waterDensity 1025.0
sampleParams 3600.0 0.1
seawayType uniSpectrum
begin uniSpectrumSeaway
    uniWaveFreqRange 0.2 2.0 0.05 randomInc 1001 1003
    uniPhaseSeeds 1001 1003
    uniThreshold 1.0e-6
    uniSpectrumType uniBretschneider
    uniBretParam 0.0 3.25 9.7
end uniSpectrumSeaway
plotOutOption screen
begin plots
    plotOptions png blueTurquoise smooth mesh
    plotFileName bretSeaState5.png
    xfRange 0.0 400.0 10.0
    yfRange 0.0 400.0 10.0
    time 0.0
    viewPoint -100.0 -100.0 100.0
    zoomFactor 1.5
    imageSize 150.0 100.0
end plots
end SM3DBuildSeaway
```

## D.3 Sample Output File for SM3DBuildSeaway

Program SM3DBuildSeaway

ShipMo3D library Version 1.0c - 26 November 2007

Time : Wed Feb 06 15:31:40 2008

Run label:

Hs = 3.25 m, Tp = 9.7 s, Bretschneider spectrum

\*\*\*\* ECHO OF USER INPUT \*\*\*\*

Wave heading convention is 0 deg for waves from north, 90 deg from east

Phase convention is lead of crest at origin xf=0, yf=0

Output seaway file name: bretSeaState5.pkl

Water density : 1025.000 kg/m3

Parameters for sampling of seaway statistics (input)

Duration : 3600.000 s

Interval : 0.100 s

Seaway type : uniSpectrum

Seaway from uni-directional wave spectrum

Minimum wave frequency : 0.200 rad/s

Maximum wave frequency : 2.000 rad/s

Wave frequency increment : 0.050 rad/s

Option for random adjustment of wave frequency increment: randomInc

Seed numbers for random adjustment of wave freq increment: 1001 1003

Wave frequencies (rad/s)

0.200	0.270	0.318	0.337	0.407	0.445	0.489	0.562
0.591	0.631	0.689	0.736	0.786	0.835	0.918	0.944
0.991	1.049	1.110	1.149	1.181	1.236	1.297	1.350
1.391	1.464	1.484	1.545	1.586	1.635	1.689	1.746
1.791	1.854	1.888	1.953	2.000			

User input wave component seed numbers: 1001 1003

User input threshold for relative energy : 1.0e-006

Parameters for unidirectional Bretschneider spectrum

Wave heading 0.000 deg (from)

Significant wave height 3.250 m

Peak wave period 9.700 s

Plot output option : screen

Seaway plot parameters

File format : png

Colour table : blueTurquoise

Smooth shade option : smooth

Mesh option : mesh  
 Plot file name : bretSeaState5.png  
 xf min, max, and increment : 0.000 400.000 10.000  
 yf min, max, and increment : 0.000 400.000 10.000  
 Time of seaway for plot : 0.000 s  
 View point location : -100.000 -100.000 100.000  
 Zoom factor : 1.500 (input)  
 Image width and height (mm) : 150.0 100.0 (input)

\*\*\*\* PROPERTIES OF MULTI-COMPONENT SEAWAY \*\*\*\*

Multi-component seaway in earth-fixed axes  
 Significant wave height assuming random phases : 3.224 m

Wave component properties

Heading (deg)	Frequency (rad/s)	Amplitude (m)	Phase (deg)
0.000	0.407	0.043	134.422
0.000	0.445	0.099	77.577
0.000	0.489	0.227	291.986
0.000	0.562	0.342	96.537
0.000	0.591	0.300	5.607
0.000	0.631	0.377	82.607
0.000	0.689	0.385	53.354
0.000	0.736	0.351	54.990
0.000	0.786	0.328	43.860
0.000	0.835	0.346	340.609
0.000	0.918	0.267	125.050
0.000	0.944	0.207	95.314
0.000	0.991	0.226	171.860
0.000	1.049	0.213	271.170
0.000	1.110	0.173	175.365
0.000	1.149	0.134	7.774
0.000	1.181	0.140	54.297
0.000	1.236	0.146	151.234
0.000	1.297	0.129	178.403
0.000	1.350	0.107	101.695
0.000	1.391	0.109	303.644
0.000	1.464	0.087	38.766
0.000	1.484	0.079	133.479
0.000	1.545	0.080	49.623
0.000	1.586	0.071	42.004
0.000	1.635	0.070	77.974
0.000	1.689	0.068	141.484
0.000	1.746	0.060	96.847

0.000	1.791	0.058	219.399
0.000	1.854	0.050	72.818
0.000	1.888	0.048	208.891
0.000	1.953	0.047	349.151
0.000	2.000	0.029	253.119

\*\*\*\* Wave elevation time series statistics \*\*\*\*

Mean	:	-0.001 m
Standard deviation	:	0.804 m
Minimum	:	-2.808 m
Maximum	:	2.916 m
Zero-crossing period	:	7.355 s
Significant wave height	:	3.220 m

# Annex E: Files for Simulating Motions of Freely Maneuvering Ship with SM3DFreeMo

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## E.1 Format of Input File for Simulating Motion of a Freely Maneuvering Ship for SM3DFreeMo

### Record (a), Beginning Record

“begin SM3DFreeMo” (1 character string with 2 words)

### Record (b), Run Label

“label”, label (2 character strings)

“label”    Record tag.

label      Label for run. This can include spaces.

### Record (c), Input Ship Database File Name

“freeShipDBTDFFileName”, freeShipDBTDFFileName (2 character strings)

“freeShipDBTDFFileName”    Record tag.

freeShipDBTDFFileName      Name of input ship database file in Python pickle format. This file must have been created using program SM3DBuildShip.

### Record (d), Ship Loading Condition

“loadCondition”, waterDensity, draftBlMid, trimBlStern, shipKG, correctionGM (1 character string, 5 floats)

“loadCondition”    Record tag.

waterDensity      Water density ( $\text{kg/m}^3$ ).

draftBlMid        Draft of baseline at midships (m).

trimBlStern       Trim of baseline by stern (m).

shipKG            Height of centre of gravity above baseline (m).

correctionGM      Correction to metacentric height (m).

**Note:**            The values in this record must agree with the values used for the ship database file specified in Record (c). Values are considered to be in agreement when they are within a tolerance of  $0.001 \text{ kg/m}^3$  for density, and  $0.001 \text{ m}$  for draft, trim, height of CG, and metacentric height. The output file from SM3DBuildShip gives the values of the above parameters.

### **Record (e), Beginning of Rudder Autopilot Settings**

“begin rudderAutopilotSettings” (2 character strings)

Records (e) to (e7) are optional.

“begin rudderAutopilotSettings”    Record tag.

#### **Note:**

Records (e) to (e7) are optional and can be used to supersede autopilot settings for a ship defined by SM3DBuildShip given in the file of (c). Within Records (e) to (e7), Records (e1) to (e4) can be repeated an arbitrary number of times to set rudder autopilot parameters as required.

### **Record (e1), Rudder Index for Autopilot Settings**

“indexRudderAutopilot” indexRudderAutopilot (1 character string, 1 integer)

This Record must follow Record (e) if autopilot settings are being given as input.

“indexRudderAutopilot”    Record tag.

indexRudderAutopilot    Index of rudder for which autopilot settings are being specified. Rudder indices range from 0 to nRudder−1, where nRudder is the number of ship rudders. If this rudder to set to −1, then the input autopilot settings are applied to all rudders.



## Record (e2), Rudder Autopilot Parameters

This record can optionally be entered if an autopilot index has been specified using Record (e1)

“autoPilotParam”, deflectMaxDeg, velMaxDeg, accMaxDeg, freqResponse, dampResponse, dtMax (1 character string, 6 floats)

“autoPilotControlParam”    Record tag

deflectMaxDeg                Maximum rudder deflection angle (deg). This value is typically set to 35°.

velMaxDeg                    Maximum rudder deflection velocity (deg/s). If this value is set to 0.0, then the maximum velocity is unlimited.

accMaxDeg                    Maximum rudder acceleration (deg/s<sup>2</sup>). If this value is set to 0.0, then the maximum acceleration is unlimited.

freqResponse                Undamped response frequency of rudder autopilot.

dampResponse                Damping of rudder autopilot as a fraction of critical damping. This value is typically between 0.5 and 1.0

dtMax                        Maximum time increment for time stepping of rudder motions. If this value is set to 0.0, then the no limit is applied and time stepping is done using the same time increment as for ship motions.

**Note:**                      If this record is not included after Record (e1), then the original values for the given ship rudder autopilot are used.

### Record (e3), Rudder Autopilot Displacement Gains

This record can optionally be entered if an autopilot index has been specified using Record (e1)

“dispGains”, surgeGain, swayGain, heaveGain, rollGain, pitchGain, yawGain (1 character string, 6 floats)

“dispGains”     Record tag

surgeGain     Surge gain (deg/m). This value is typically 0.0.

swayGain     Sway gain (deg/m). This value is typically 0.0.

heaveGain     Heave gain (deg/m). This value is typically 0.0.

rollGain     Roll gain (deg/deg). This value is typically 0.0 unless rudder roll stabilization is desired.

pitchGain     Pitch gain (deg/deg). This value is typically 0.0.

yawGain     Yaw gain (deg/deg). Note that input yaw gain is defined according to ship motions in earth-fixed axes, for which positive yaw motion is clockwise. For a typical ship with a downward oriented rudder, this value is typically  $\leq 0.0$ .

**Note:**     If this record is not included after Record (e1), then the original values for the given ship rudder autopilot are used.

### Record (e4), Rudder Velocity Gains

This record can optionally be entered if an autopilot index has been specified using Record (e1).

“velGains”, surgeVelGain, swayVelGain, heaveVelGain, rollVelGain, pitchVelGain, yawVelGain (1 character string, 6 floats)

“velGains”     Record tag

surgeVelGain     Surge velocity gain (deg/(m/s)). This value is typically 0.0.

swayVelGain     Sway velocity gain (deg/(m/s)). This value is typically 0.0.

heaveVelGain     Heave velocity gain (deg/(m/s)). This value is typically 0.0.

rollVelGain     Roll velocity gain (deg/(deg/s)). This value is typically 0.0 unless rudder stabilization is desired.

pitchVelGain     Pitch velocity gain (deg/(deg/s)). This value is typically 0.0.

yawVelGain     Yaw velocity gain (deg/(deg/s)). Note that input yaw gain is defined according to ship motions in earth-fixed axes, for which positive yaw motion is clockwise. For a typical ship with a downward oriented rudder, this value is typically  $\leq 0.0$ .

**Note:**     If this record is not included after Record (e1), then the original values for the given ship rudder autopilot are used.

### **Record (e5), Rudder Integral Gains**

This record can optionally be entered if an autopilot index has been specified using Record (e1).

“intGains”, surgeIntGain, swayIntGain, heaveIntGain, rollIntGain, pitchIntGain, yawIntGain (1 character string, 6 floats)

“intGains”	Record tag
surgeIntGain	Surge integral gain (deg/(m·s)). This value should be 0.0.
swayIntGain	Sway integral gain (deg/(m·s)). This value should be 0.0.
heaveIntGain	Heave integral gain (deg/(m·s)). This value is typically 0.0.
rollIntGain	Roll integral gain (deg/(deg·s)). This value is typically 0.0 unless rudder stabilization is desired.
pitchIntGain	Pitch integral gain (deg/(deg·s)). This value is typically 0.0.
yawIntGain	Yaw integral gain (deg/(deg·s)). For a typical ship with a downward oriented rudder, this value is typically $\leq 0.0$ .

### **Record (e6), Rudder Autopilot Integration Time**

This record can optionally be entered if an autopilot index has been specified using Record (e1).

“integrationTime”, integrationTime (1 character string, 1 float)

“integrationTime”	Record tag
integrationTime	Integration time for rudder autopilot (s).

### **Record (e7), End of Rudder Autopilot Settings**

“end rudderAutopilotSettings” (2 character strings)

“end rudderAutopilotSettings” Record tag.

### **Record (f), Seaway Option**

“seawayOption”, seawayOption (2 character strings)

“seawayOption”	Record tag.
seawayOption	Option for seaway. waves - The simulation includes a seaway with waves. calm - The simulation is in calm water.

### **Record (g), Input Seaway File Name**

This record should only be given if seawayOption in Record (f) is set to waves.

“seawayFileName”, seawayFileName (2 character strings)

“seawayFileName” Record tag.

seawayFileName Name of input seaway file in Python pickle format. This file must have been created using program SM3DBuildSeaway.

### **Record (h), Time Parameters**

“timeParameters”, dtMax, t0, tEndRampWave, tBeginStats (1 character string, 4 floats)

“timeParameters” Record tag.

dtMax Time step for motion computations (s). A suitable time step value depends mainly on the size of the ship, and to a lesser extent on the encountered conditions. A value of 0.2 s has been shown to give reliable results for a naval frigate.

t0 Start time of simulation.

tEndRampWave End time for reducing wave excitation forces (s). If tEndRampWave is greater than t0, then a ramp function increasing from 0.0 at t0 to 1.0 at tEndRampWave will be applied to wave excitation forces. This feature can be used to reduce transients at the beginning of a simulation.

tBeginStats Beginning time for sampling motion statistics (s).

### **Record (i), Nonlinear Option for Incident (Froude-Krylov) Wave Forces and Buoyancy Forces**

“nonLinearOption”, nonLinearOption (2 character strings)

“nonLinearOption” Record tag.

nonLinearOption Option for using nonlinear computations of forces due to incident waves and buoyancy.

nonLinear - Nonlinear computation of forces due to incident waves and buoyancy. If this option is used, then the ship file produced by SM3DBuildShip and specified in Record (c) must include a dry panelled hull.

linear - Linear computation of forces due to incident waves and buoyancy.

### Record (j), Initial Ship Position

“dispsFixed0MDeg”, dispsFixed0MDeg (1 character string, 6 floats)  
“dispsFixed0MDeg” Record tag.  
dispsFixed0MDeg Initial ship position in earth-fixed coordinates:  
 $x^f$  of ship CG (m, + north)  
 $y^f$  of ship CG (m, + west)  
Heave  $\eta_3$  of ship CG relative to calm water position (m, + up)  
Roll  $\eta_4$  (deg, + port up)  
Pitch  $\eta_5$  relative to calm water position (deg, + bow down)  
Ship heading  $\chi$  (deg, 0° for north, 90° for east)

### Record (k1), Initial Ship Speed

The input file must include one of Records (k1), (k2), or (k3).  
“speed0”, speed0 (1 character string, 1 float)  
“speed0” Record tag.  
speed0 Initial ship speed along the heading given in Record (j) (m/s).

### Record (k2), Initial Ship Speed in Knots

The input file must include one of Records (k1), (k2), or (k3).  
“speed0Knots”, speed0Knots (1 character string, 1 float)  
“speed0Knots” Record tag.  
speed0Knots Initial ship speed along the heading given in Record (j) (knots).

### Record (k3), Initial Ship Velocity for Six Degrees of Freedom

The input file must include one of Records (k1), (k2), or (k3).  
“velsFixed0MDeg”, velsFixed0MDeg (1 character string, 6 floats)  
“velsFixed0MDeg” Record tag.  
velsFixed0MDeg Initial ship velocity in earth-fixed coordinates:  
 $\dot{x}^f$  of ship CG (m/s, + north)  
 $\dot{y}^f$  of ship CG (m/s, + west)  
Heave velocity  $\eta_3$  of ship CG (m/s, + up)  
Roll velocity  $\eta_4$  (deg/s, + port up)  
Pitch velocity  $\eta_5$  relative to calm water position (deg/s, + bow down)  
Ship heading velocity  $\dot{\chi}$  (deg/s, + clockwise viewed from above)

### **Record (l), Initial Rudder Deflections**

This record is optional.

“rudderDeflects0Deg”, rudderDeflects0Deg (1 character string, nRudder floats)

“rudderDeflects0Deg”    Record tag.

rudderDeflects0Deg    Initial rudder deflections (deg, + counter-clockwise viewed from inside hull). If this record is not given, then defaults of 0° are used. If this record is given, then the number of values should correspond with the number of rudders in the ship file specified by Record (c).

### **Record (m), Initial Rudder Velocities**

This record is optional.

“rudderVels0Deg”, rudderVels0Deg (1 character string, nRudder floats)

“rudderVels0Deg”    Record tag.

rudderVels0Deg    Initial rudder velocities (deg/s, + counter-clockwise viewed from inside hull). If this record is not given, then defaults of 0 deg/s are used. If this record is given, then the number of values should correspond with the number of rudders in the ship file specified by Record (c).

### **Record (n), Initial Propeller RPMs**

This record is optional.

“rpmsPropellers0”, rpmsPropellers0 (1 character string, nPropeller floats)

“rpmsPropellers0”    Record tag.

rpmsPropellers0    Initial propeller RPM values. If this record is not given, then defaults of 0 RPM are used. If this record is given, then the number of values should correspond with the number of propellers in the ship file specified by Record (c).

### **Record (o), Beginning of Maneuvers**

This record can be followed by Records (o1) to (o7) repeated in arbitrary order.

“begin maneuvers”(1 character string with 2 words)

### **Record (o1), Propeller RPM Command**

This record is optional.

“setRpm”, indexPropeller, rpmCommand (1 character string, 1 integer, 1 float)

“setRpm”	Record tag.
indexPropeller	Index for propeller. The first propeller has index 0. A value of $-1$ sets all propellers.
rpmCommand	Command propeller RPM (RPM).

### **Record (o2), Course Command**

This record is optional.

“setCourse”, indexRudder, shipHeadingToCommandDeg (1 character string, 1 integer, 1 float)

“setCourse”	Record tag.
indexRudder	Index for rudder. The first rudder has index 0. A value of $-1$ sets all rudders.
shipHeadingToCommandDeg	Ship heading $\chi$ (deg) to which autopilot is set.

### **Record (o3), Rudder Deflection Command**

This record is optional.

“setRudder”, indexRudder, deflectCommandDeg (1 character string, 1 integer, 1 float)

“setRudder”	Record tag.
indexRudder	Index for rudder. The first rudder has index 0. A value of $-1$ sets all rudders.
deflectCommandDeg	Command rudder deflection angle (deg, + counter-clockwise viewed from inside the hull). For a ship with a conventional rudder pointing downward, a positive rudder deflection turns the ship to starboard.

### **Record (o4), Turn to Absolute Heading Maneuver Command**

This record is optional.

“turnAbsHeading”, finalHeadingDeg, tElapsedMax (optional) (1 character string, 1 or 2 floats)

“turnAbsHeading”	Record tag.
finalHeadingDeg	Ship heading $\chi$ (deg, 0 for north) at which the program considers the command completed. To ensure completion of a turn, a setRudder command should normally be made before a turnAbsHeading command.
tElapsedMax	Time limit (s) for attempting to reach heading finalHeadingDeg. If this input is not included, then a default value of 3600 s is used.

### **Record (o5), Turn Change in Heading Maneuver Command**

This record is optional.

“turnDeltaHeading”, deltaHeadingDeg, tElapsedMax (optional) (1 character string, 1 or 2 floats)

“turnDeltaHeading”	Record tag.
deltaHeadingDeg	Change from initial heading at which the program considers the turn maneuver completed. To ensure completion of a turn, a setRudder command should normally be made before a turnDeltaHeading command.
tElapsedMax	Time limit (s) for attempting to reach change in heading deltaHeadingDeg. If this input is not included, then a default value of 3600 s is used.

### **Record (o6), Straight Distance Maneuver Command**

This record is optional.

“straightDistance”, distance, tElapsedMax (optional) (1 character string, 1 or 2 floats)

“straightDistance”	Record tag.
distance	Straight line distance (m) between start and end points at which the program considers the maneuver completed.
tElapsedMax	Time limit (s) for attempting to traverse distance straightDistance. If this input is not included, then a default value of 3600 s is used.



### **Record (o7), Elapsed Time Maneuver Command**

This record is optional.

“elapsedTime”, tElapsedMax (1 character string, 1 float)

“elapsedTime” Record tag.

tElapsedMax Elapsed time at which the program considers the maneuver completed.

### **Record (o8), End of Maneuvers**

This record is required after all maneuvers described using Records (o1) to (o7).

“end maneuvers”(1 character string with 2 words)

### **Record (p), Time Intervals for Output Time Series and Console**

“outTimeIntervals”, dtOutTimeSeries, dtOutConsole (1 character string, 1 float)

“outTimeIntervals” Record tag.

dtOutTimeSeries Time interval for output time series written to file (s). If this value is set to  $\leq$  dtMax from Record (h), then output values will be at an interval of dtMax.

dtOutConsole Time interval for written simulation progress to console. If this value is set to  $\leq$  dtMax from Record (h), then output values will be at an interval of dtMax.

### **Record (q), Output Ship Motion Time Interval and Options**

“outTimeSeries”, dispOutOption, velOutOption, accOutOption (4 character strings)

“outTimeSeries” Record tag.

dispOutOption Option for giving output ship displacements.  
disp - Output displacements are given.  
noDisp - No output displacements are given.

velOutOption Option for giving output ship velocities.  
vel - Output velocities are given.  
noVel - No output velocities are given.

accOutOption Option for giving output ship accelerations.  
acc - Output accelerations are given.  
noAcc - No output accelerations are given.

### **Record (r), Output Rudder and Propeller Time Series Options**

“outRudderProp”, rudderOutOption, propOutOption (3 character strings)  
“outRudderProp” Record tag.  
rudderOutOption Option for giving output rudder motions.  
rudder - Output rudder times series are given.  
noRudder - No rudder time series are given.  
propOutOption Option for giving output propeller motions.  
prop - Output propeller times series are given.  
noProp - No propeller time series are given.

### **Record (s), Plot Option**

“plotOption”, plotOption (2 character strings)  
“plotOption” Record tag.  
plotOption Option for making plots of ship motion time series.  
noPlots - No plots are produced.  
screenFile - Plots are both plotted on the screen and to a file.  
screen - Plots are only plotted on the screen.  
file - Plots are only written to a file.

### **Record (s1), Plot File Name Prefix**

This record is optional. If the record is omitted, then no prefix is used.  
“plotNamePrefix”, plotNamePrefix (2 character strings)  
“plotNamePrefix” Record tag.  
plotNamePrefix Prefix for plot files (default is no prefix).

### **Record (s2), Plot File Format**

This record is optional. If the record is omitted, then png format is used.  
“fileFormat”, fileFormat (2 character strings)  
“fileFormat” Record tag.  
fileFormat Plot format. Available formats are bmp, eps, gif, pdf, png, ppm, ps, svg, tiff, and wmf.

**Record (s3), Image Size**

This record is optional

“plotSize”, widthmm, heightmm (1 character string, 1 float)

“plotSize” Record tag.

widthmm Plot width (mm). (Default 120 mm)

heightmm Plot height (mm). (Default 80 mm)

**Note:** If this record is omitted, then the default values are used.

**Record (t), End of Ship Motion Simulation Ship Data**

“end SM3DFreeMo” (1 character string with 2 words)

## E.2 Sample Input File for SM3DFreeMo

```
begin SM3DFreeMo
label Generic frigate in long-crested Bretschneider sea state 5
freeShipDBTDFileName genFrigFreeShip.pkl
loadCondition 1025.0 4.2 0.0 6.0 0.0
seawayOption waves
seawayFileName bretSeaState5.pkl
timeParameters 0.2 0.0 20.0 20.0
nonLinearOption linear
dispsFixed0MDeg 0.0 0.0 0.0 0.0 0.0 0.0
speed0Knots 20.0
rudderDeflects0Deg 0.0
rudderVels0Deg 0.0
rpmsPropellers0 129.0 129.0
begin maneuvers
    setRpm -1 200.0
    setCourse -1 0.0
    elapsedTime 20.0
    setCourse -1 90.0
    elapsedTime 100.0
end maneuvers
outTimeIntervals 0.4 10.0
outTimeSeries disp noVel noAcc
outRudderProp noRudder noProp
plotOption screen
end SM3DFreeMo
```

## E.3 Sample Output File for SM3DFreeMo

Program SM3DFreeMo  
ShipMo3D library Version 1.0c - 26 November 2007  
Time : Wed Feb 06 15:32:13 2008  
Run label:  
Generic frigate in long-crested Bretschneider sea state 5

\*\*\*\* ECHO OF USER INPUT \*\*\*\*

Input ship database file name:  
genFrigFreeShip.pkl

Ship Loading Condition  
Water density : 1025.000 kg/m3  
Draft of baseline at midships : 4.200 m  
Trim of baseline by stern : 0.000 m  
Height of CG above baseline, KG : 6.000 m  
Correction to metacentric height GM : 0.000 m  
Seaway option : waves  
Seaway file name:  
bretSeaState5.pkl

Time parameters  
Time step : 0.200 s  
Initial time : 0.000 s  
End of wave ramp function : 20.000 s  
Beginning of statistics sampling : 20.000 s

Option for nonlinear buoyancy and incident wave forces : linear

Initial ship position  
xf : 0.000 m (+ north)  
yf : 0.000 m (+ west)  
Heave : 0.000 m (+ up, relative to calm water position)  
Roll : 0.000 deg (+ port up)  
Pitch : 0.000 deg (+ bow down)  
Heading : 0.000 deg (0 north, 90 east)

Initial ship speed : 20.000 knots

Initial ship velocity components  
xf velocity : 10.300 m/s (+ north)  
yf velocity : 0.000 m/s (+ west)  
Heave velocity : 0.000 m/s (+ up, relative to calm water position)  
Roll velocity : 0.000 deg/s (+ port up)  
Pitch velocity : 0.000 deg/s (+ bow down)  
Heading velocity : 0.000 deg/s (0 north, 90 east)  
Initial rudder deflections (deg) (input)  
0.000

Initial rudder velocities (deg/s) (input)  
0.000  
Initial propeller RPMs (input)  
129.000 129.000

Beginning of maneuvering commands  
setRpm -1 200.0  
setCourse -1 0.0  
elapsedTime 20.0  
setCourse -1 90.0  
elapsedTime 100.0  
End of maneuvering commands

**\*\* Output options for time series**

Output file time interval : 0.400 s  
Time interval for console message : 10.000 s  
Options for writing time series to files  
Displacements : disp  
Velocities : noVel  
Accelerations : noAcc  
Rudder deflections : noRudder  
Propeller RPM : noProp

**\*\* Output plot options**

Plot option : screen  
Plot file format : png  
Plot width : 120 mm  
Plot height : 80 mm

**\*\*\*\* SHIP LOADING CONDITION \*\*\*\***

Generic frigate  
Load Condition Properties for Trimmed Ship

Summary of hydrostatic properties

Number of panels on port side	:	624
Length between perpendiculars	:	120.000 m
Draft of baseline at midships	:	4.200 m
Trim of baseline by stern	:	0.000 m
Beam based on maximum y value	:	14.115 m
Volume	:	3625.687 m3
Water density	:	1025.000 kg/m3
Mass	:	3716329.367494 kg
LCB of aft of FP (m)	:	61.739 m
X origin aft of FP (m)	:	61.739 m
X value of LCB	:	0.000 m
Center of buoyancy wrt waterline	:	-1.620 m
Wetted surface area	:	1754.193 m2

Waterplane area : 1344.547 m2  
 X value of center of floatation : -5.016 m  
 Integral of waterplane area\*X\*\*2 : 1235150.552 m4  
 Integral of waterplane area\*Y\*\*2 : 17543.034 m4  
 KG, height of CG above baseline : 6.000 m  
 Height of CG above waterline : 1.800 m  
 Metacentric height from hydrostatics : 1.418 m

#### Inertial Properties

Inertia matrix, units of kg, kg\*m, and kg\*m2

3716329.4	0.0	0.0	0.0	0.0	0.0
0.0	3716329.4	0.0	0.0	0.0	0.0
0.0	0.0	3716329.4	0.0	0.0	0.0
0.0	0.0	0.0	85624228.6	0.0	0.0
0.0	0.0	0.0	0.0	3344696430.7	0.0
0.0	0.0	0.0	0.0	0.0	3344696430.7

Roll radius of gyration : 4.800 m  
 Pitch radius of gyration : 30.000 m  
 Yaw radius of gyration : 30.000 m

#### Roll Metacentric Height Properties

Correction to roll metacentric height : 0.000 m  
 Corrected metacentric height : 1.418 m

#### Roll Properties at Zero Forward Speed

Roll added mass : 19364305.058549 kg\*m\*\*2  
 Nondimensional roll added mass A44/I44 : 0.226  
 Natural roll frequency : 0.702 rad/s  
 Natural roll period : 8.956 s

#### \*\*\*\* SHIP AUTOPILOT SETTINGS \*\*\*\*

Generic frigate  
 Autopilots for Ship

Autopilot index : 0  
 Autopilot for freely maneuvering ship  
 Label: Rudder  
 Maximum deflection : 35.000 deg  
 Maximum velocity : 3.000deg/s  
 Maximum acceleration : Not set  
 Response frequency : 3.000 rad/s  
 Response damping : 0.850 rad/s (fraction of critical)  
 Maximum time step for computing deflections : 0.100s  
 Autopilot gains

Yaw gains given relative to earth-fixed axes (+yaw is clockwise)

	xf	yf	Heave	Roll	Pitch	Yaw
Displacement gains (deg/m and deg/deg)	0.000	0.000	0.000	0.000	0.000	-4.000
Velocity gains (deg/(m/s) and deg/(deg/s))	0.000	0.000	0.000	0.000	0.000	-8.000
Integral gains (deg/(m*s) and deg/(deg*s))	0.000	0.000	0.000	0.000	0.000	0.000

Integration time : 0.000 s

\*\*\*\* SIMULATING SHIP MOTIONS \*\*\*\*

Executing command at time 0.000 s  
setRpm -1 200.0

Executing command at time 0.000 s  
setCourse -1 0.0

setCourse 0.0  
Executing command at time 0.000 s  
elapsedTime 20.0

Executing command at time 20.200 s  
setCourse -1 90.0

setCourse 90.0  
Executing command at time 20.200 s  
elapsedTime 100.0

\*\*\*\* COMPUTED SHIP MOTIONS \*\*\*\*

Time series summary  
Beginning and end times for statistics(s) 20.200 120.200  
Displacements, xf and yf in earth-fixed axes

Mode	Mean	Dev	Max	Min	tz (s)
xf (m)	545.097	118.834	630.891	217.352	0.000
yf (m)	-285.107	253.242	0.230	-796.377	0.000
heave (m)	0.007	0.689	2.293	-2.066	6.586
roll (deg)	-0.045	2.855	5.559	-5.799	9.350
pitch (deg)	0.011	0.871	3.193	-3.885	5.625
heading (to) (deg)	64.588	32.737	93.967	-0.000	0.000
Rudder deflections (deg)					
Rudder	15.109	16.748	35.641	-10.533	0.000

Velocities, uf and vf in earth-fixed axes

Mode	Mean	Dev	Max	Min	tz (s)
uf (m/s)	4.052	4.664	11.760	-1.154	0.000
vf (m/s)	-7.964	4.168	0.067	-11.947	0.000
heave (m/s)	-0.005	0.685	2.380	-2.180	5.788
roll (deg/s)	-0.000	1.949	5.524	-4.626	6.154



pitch (deg/s)	-0.006	0.932	4.139	-4.115	5.300
heading (to) (deg/s)	0.900	0.991	2.645	-0.696	0.000
Rudder velocities (deg/s)					
Rudder	0.001	1.647	3.025	-3.004	12.300
Propeller RPM					
Propeller (port)	200.000	0.000	200.000	200.000	0.000
Propeller (starboard)	200.000	0.000	200.000	200.000	0.000

#### Ship speed along instantaneous heading

Speed (m/s)	10.822	0.912	11.947	9.339	0.000
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#### Accelerations, xf and yf acceleration in earth-fixed axes

Mode	Mean	Dev	Max	Min	tz (s)
acc-xf (m/s <sup>2</sup> )	-0.113	0.299	0.687	-0.762	6.657
acc-yf (m/s <sup>2</sup> )	-0.119	0.118	0.030	-0.519	5.760
heave (m/s <sup>2</sup> )	-0.001	0.727	2.335	-2.569	5.835
roll (deg/s <sup>2</sup> )	-0.041	1.847	6.431	-5.892	6.500
pitch (deg/s <sup>2</sup> )	-0.006	1.075	5.103	-4.256	5.021
heading (to) (deg/s <sup>2</sup> )	-0.001	0.208	0.851	-0.829	6.129

#### Time series of ship displacements

All values given for ship centre of gravity

xf - Horizontal earth-fixed coordinate (m, + north)  
yf - Horizontal earth-fixed coordinate (m, + west)  
Heave - Heave relative to value in calm water (m, + up)  
Roll - Roll relative to value in calm water (deg, + port up)  
Pitch - Pitch relative to value in calm water (deg, + bow down)  
Heading - Heading (deg, 0 for north, 90 for east)

Time (s)	xf (m)	yf (m)	Heave (m)	Roll (deg)	Pitch (deg)	Heading (deg)
0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.400	4.112	-0.000	0.001	0.000	0.003	-0.000
0.800	8.210	-0.000	0.002	-0.000	0.019	-0.000
1.200	12.293	-0.000	-0.001	-0.000	0.047	-0.000
1.600	16.362	-0.000	-0.009	-0.000	0.081	-0.000
2.000	20.417	-0.000	-0.023	0.000	0.103	-0.000
2.400	24.459	-0.000	-0.040	0.000	0.087	0.000
2.800	28.488	-0.000	-0.053	0.000	0.018	0.000
3.200	32.507	-0.000	-0.053	0.000	-0.092	0.000
3.600	36.522	-0.000	-0.035	0.000	-0.218	0.000
4.000	40.542	-0.000	0.002	0.000	-0.328	0.000
4.400	44.577	-0.000	0.050	-0.000	-0.380	0.000
4.800	48.633	-0.000	0.099	-0.000	-0.337	0.000
5.200	52.709	-0.000	0.131	-0.000	-0.201	0.000
5.600	56.809	-0.000	0.131	-0.000	0.000	0.000
6.000	60.931	-0.000	0.098	-0.000	0.231	0.000
6.400	65.077	-0.000	0.037	-0.000	0.434	0.000
6.800	69.248	-0.000	-0.038	-0.000	0.540	0.000
7.200	73.444	-0.000	-0.107	-0.000	0.507	0.000
7.600	77.666	-0.000	-0.152	0.000	0.346	0.000

8.000	81.912	-0.000	-0.162	0.000	0.104	0.000
8.400	86.180	-0.000	-0.136	0.000	-0.161	0.000
8.800	90.466	-0.000	-0.084	0.000	-0.383	0.000
9.200	94.764	-0.000	-0.016	0.000	-0.504	-0.000
9.600	99.071	-0.000	0.054	0.000	-0.503	-0.000
10.000	103.385	-0.000	0.117	0.000	-0.402	-0.000
10.400	107.705	-0.000	0.164	0.000	-0.244	-0.000
10.800	112.034	-0.000	0.190	0.000	-0.065	-0.000
11.200	116.375	-0.000	0.191	0.000	0.095	-0.000
11.600	120.733	-0.000	0.162	0.000	0.201	0.000
12.000	125.110	-0.000	0.107	0.000	0.239	0.000
12.400	129.506	-0.000	0.035	0.000	0.225	0.000
12.800	133.923	-0.000	-0.046	-0.000	0.181	0.000
13.200	138.358	-0.000	-0.126	-0.000	0.137	-0.000
13.600	142.808	-0.000	-0.191	-0.000	0.131	-0.000
14.000	147.272	-0.000	-0.231	-0.000	0.182	-0.000
14.400	151.751	-0.000	-0.243	-0.000	0.247	-0.000
14.800	156.243	-0.000	-0.237	-0.000	0.272	-0.000
15.200	160.749	-0.000	-0.217	-0.000	0.233	0.000
15.600	165.267	-0.000	-0.189	-0.000	0.113	0.000
16.000	169.794	-0.000	-0.157	0.000	-0.092	0.000
16.400	174.327	-0.000	-0.111	0.000	-0.329	0.000
16.800	178.860	-0.000	-0.037	0.000	-0.526	0.000
17.200	183.389	-0.000	0.073	0.000	-0.651	0.000
17.600	187.911	-0.000	0.214	0.000	-0.701	0.000
18.000	192.425	-0.000	0.372	0.000	-0.664	0.000
18.400	196.937	-0.000	0.515	0.000	-0.546	0.000
18.800	201.451	-0.000	0.607	0.000	-0.366	0.000
19.200	205.975	-0.000	0.617	0.000	-0.123	0.000
19.600	210.513	-0.000	0.531	0.000	0.171	0.000
20.000	215.068	-0.000	0.349	-0.000	0.446	0.000
20.400	219.640	-0.000	0.103	-0.000	0.670	-0.000
20.800	224.230	0.000	-0.160	0.003	0.846	0.001
21.200	228.846	0.002	-0.403	0.026	0.957	0.006
21.600	233.490	0.007	-0.601	0.094	0.999	0.022
22.000	238.159	0.016	-0.735	0.229	0.979	0.055
22.400	242.849	0.030	-0.801	0.444	0.847	0.109
22.800	247.550	0.048	-0.793	0.737	0.545	0.186
23.200	252.254	0.070	-0.697	1.097	0.081	0.291
23.600	256.952	0.095	-0.505	1.506	-0.474	0.424
24.000	261.638	0.122	-0.227	1.939	-1.023	0.587
24.400	266.306	0.149	0.106	2.371	-1.427	0.781
24.800	270.955	0.174	0.445	2.779	-1.557	1.005
25.200	275.588	0.197	0.721	3.138	-1.403	1.259
25.600	280.201	0.215	0.877	3.431	-1.030	1.543
26.000	284.793	0.227	0.901	3.643	-0.527	1.858
26.400	289.371	0.230	0.805	3.760	-0.035	2.205
26.800	293.941	0.225	0.622	3.787	0.333	2.585
27.200	298.514	0.209	0.398	3.734	0.593	2.995
27.600	303.103	0.180	0.163	3.604	0.813	3.434
28.000	307.713	0.137	-0.076	3.397	0.995	3.902

28.400	312.340	0.076	-0.312	3.113	1.125	4.401
28.800	316.980	-0.005	-0.522	2.779	1.176	4.933
29.200	321.626	-0.109	-0.680	2.422	1.067	5.502
29.600	326.271	-0.239	-0.755	2.076	0.775	6.105
30.000	330.911	-0.397	-0.721	1.773	0.363	6.740
30.400	335.539	-0.585	-0.587	1.523	-0.099	7.405
30.800	340.149	-0.806	-0.377	1.340	-0.519	8.098
31.200	344.732	-1.062	-0.126	1.212	-0.808	8.817
31.600	349.284	-1.355	0.120	1.150	-0.963	9.557
32.000	353.795	-1.685	0.325	1.183	-1.006	10.319
32.400	358.262	-2.049	0.469	1.331	-0.925	11.103
32.800	362.688	-2.450	0.543	1.599	-0.725	11.904
33.200	367.079	-2.890	0.543	1.923	-0.431	12.715
33.600	371.440	-3.373	0.478	2.173	-0.052	13.529
34.000	375.777	-3.904	0.359	2.261	0.362	14.342
34.400	380.098	-4.480	0.192	2.191	0.685	15.154
34.800	384.403	-5.100	-0.001	2.010	0.847	15.965
35.200	388.695	-5.766	-0.184	1.723	0.868	16.778
35.600	392.977	-6.481	-0.333	1.335	0.766	17.594
36.000	397.244	-7.247	-0.424	0.861	0.566	18.423
36.400	401.490	-8.067	-0.439	0.316	0.328	19.266
36.800	405.709	-8.942	-0.376	-0.280	0.093	20.117
37.200	409.898	-9.872	-0.251	-0.868	-0.138	20.972
37.600	414.052	-10.856	-0.090	-1.351	-0.362	21.833
38.000	418.167	-11.891	0.080	-1.687	-0.551	22.698
38.400	422.239	-12.980	0.236	-1.886	-0.666	23.558
38.800	426.273	-14.121	0.354	-1.934	-0.684	24.406
39.200	430.268	-15.311	0.416	-1.799	-0.603	25.246
39.600	434.225	-16.549	0.419	-1.486	-0.415	26.079
40.000	438.147	-17.833	0.367	-1.057	-0.139	26.906
40.400	442.042	-19.164	0.263	-0.571	0.168	27.724
40.800	445.915	-20.539	0.114	-0.062	0.461	28.530
41.200	449.774	-21.958	-0.063	0.390	0.720	29.320
41.600	453.621	-23.426	-0.253	0.688	0.908	30.101
42.000	457.456	-24.943	-0.440	0.795	0.957	30.882
42.400	461.273	-26.509	-0.595	0.739	0.853	31.670
42.800	465.072	-28.124	-0.682	0.590	0.640	32.467
43.200	468.846	-29.790	-0.684	0.366	0.331	33.277
43.600	472.581	-31.512	-0.591	0.026	-0.049	34.107
44.000	476.263	-33.291	-0.397	-0.437	-0.439	34.971
44.400	479.883	-35.128	-0.114	-0.957	-0.819	35.870
44.800	483.430	-37.022	0.229	-1.428	-1.182	36.794
45.200	486.901	-38.972	0.596	-1.742	-1.459	37.722
45.600	490.299	-40.971	0.939	-1.806	-1.579	38.634
46.000	493.637	-43.013	1.195	-1.522	-1.486	39.510
46.400	496.931	-45.087	1.310	-0.873	-1.114	40.330
46.800	500.206	-47.187	1.238	0.033	-0.446	41.075
47.200	503.485	-49.308	0.950	1.058	0.435	41.744
47.600	506.788	-51.446	0.455	2.042	1.404	42.342
48.000	510.129	-53.601	-0.190	2.753	2.316	42.903
48.400	513.507	-55.784	-0.896	2.990	2.940	43.491

48.800	516.902	-58.009	-1.539	2.619	3.050	44.176
49.200	520.279	-60.294	-1.967	1.513	2.575	44.991
49.600	523.605	-62.657	-2.066	-0.215	1.524	45.933
50.000	526.854	-65.101	-1.795	-2.032	0.006	46.960
50.400	530.004	-67.617	-1.175	-3.477	-1.640	48.018
50.800	533.036	-70.201	-0.304	-4.371	-3.000	49.043
51.200	535.950	-72.839	0.648	-4.486	-3.776	50.000
51.600	538.764	-75.505	1.495	-3.605	-3.790	50.890
52.000	541.496	-78.180	2.080	-1.884	-3.009	51.712
52.400	544.172	-80.859	2.293	0.266	-1.619	52.463
52.800	546.826	-83.538	2.101	2.435	0.036	53.165
53.200	549.487	-86.220	1.551	4.212	1.583	53.848
53.600	552.173	-88.917	0.762	5.236	2.701	54.527
54.000	554.890	-91.646	-0.110	5.334	3.193	55.210
54.400	557.632	-94.417	-0.900	4.571	3.014	55.908
54.800	560.383	-97.238	-1.466	3.230	2.269	56.646
55.200	563.121	-100.114	-1.714	1.593	1.186	57.438
55.600	565.815	-103.045	-1.621	-0.138	0.044	58.292
56.000	568.435	-106.031	-1.233	-1.836	-0.915	59.210
56.400	570.958	-109.067	-0.660	-3.382	-1.549	60.164
56.800	573.383	-112.141	-0.043	-4.529	-1.799	61.111
57.200	575.720	-115.241	0.482	-5.003	-1.672	62.019
57.600	577.985	-118.360	0.817	-4.722	-1.244	62.867
58.000	580.193	-121.496	0.917	-3.805	-0.641	63.658
58.400	582.362	-124.646	0.796	-2.492	-0.002	64.415
58.800	584.506	-127.813	0.514	-1.062	0.543	65.163
59.200	586.631	-131.000	0.156	0.236	0.888	65.925
59.600	588.735	-134.213	-0.191	1.222	0.973	66.710
60.000	590.806	-137.458	-0.452	1.803	0.815	67.511
60.400	592.835	-140.739	-0.583	2.023	0.498	68.303
60.800	594.821	-144.052	-0.576	2.045	0.133	69.072
61.200	596.763	-147.392	-0.448	2.014	-0.190	69.844
61.600	598.645	-150.757	-0.227	1.904	-0.428	70.665
62.000	600.437	-154.149	0.054	1.593	-0.582	71.564
62.400	602.115	-157.569	0.354	1.061	-0.663	72.526
62.800	603.680	-161.015	0.625	0.459	-0.665	73.490
63.200	605.158	-164.484	0.811	0.059	-0.548	74.379
63.600	606.598	-167.969	0.861	0.074	-0.276	75.143
64.000	608.046	-171.467	0.746	0.476	0.132	75.795
64.400	609.528	-174.975	0.472	0.950	0.576	76.408
64.800	611.046	-178.494	0.084	1.120	0.919	77.054
65.200	612.576	-182.030	-0.337	0.772	1.046	77.770
65.600	614.080	-185.591	-0.694	-0.025	0.911	78.553
66.000	615.519	-189.180	-0.902	-0.990	0.551	79.385
66.400	616.867	-192.800	-0.912	-1.848	0.072	80.243
66.800	618.112	-196.448	-0.728	-2.464	-0.385	81.096
67.200	619.254	-200.121	-0.404	-2.803	-0.695	81.917
67.600	620.301	-203.815	-0.023	-2.869	-0.785	82.698
68.000	621.269	-207.525	0.319	-2.704	-0.659	83.449
68.400	622.175	-211.252	0.543	-2.401	-0.386	84.178
68.800	623.040	-214.995	0.601	-2.094	-0.067	84.883

69.200	623.878	-218.757	0.490	-1.898	0.201	85.555
69.600	624.697	-222.542	0.253	-1.874	0.353	86.190
70.000	625.492	-226.353	-0.036	-2.021	0.366	86.793
70.400	626.256	-230.192	-0.298	-2.303	0.263	87.376
70.800	626.974	-234.057	-0.468	-2.666	0.095	87.944
71.200	627.634	-237.947	-0.508	-3.047	-0.076	88.493
71.600	628.219	-241.861	-0.415	-3.369	-0.197	89.021
72.000	628.720	-245.796	-0.219	-3.564	-0.240	89.528
72.400	629.134	-249.752	0.028	-3.611	-0.208	90.016
72.800	629.473	-253.726	0.262	-3.548	-0.124	90.490
73.200	629.756	-257.722	0.425	-3.454	-0.024	90.944
73.600	630.002	-261.740	0.482	-3.399	0.059	91.372
74.000	630.222	-265.782	0.431	-3.421	0.106	91.769
74.400	630.420	-269.850	0.303	-3.515	0.110	92.130
74.800	630.589	-273.942	0.143	-3.653	0.081	92.458
75.200	630.724	-278.057	-0.000	-3.802	0.036	92.752
75.600	630.820	-282.193	-0.092	-3.940	-0.005	93.013
76.000	630.876	-286.349	-0.117	-4.048	-0.026	93.240
76.400	630.891	-290.524	-0.082	-4.110	-0.022	93.432
76.800	630.864	-294.716	-0.007	-4.114	0.000	93.588
77.200	630.796	-298.925	0.080	-4.060	0.022	93.712
77.600	630.685	-303.150	0.153	-3.969	0.025	93.807
78.000	630.534	-307.391	0.188	-3.886	-0.005	93.879
78.400	630.354	-311.647	0.170	-3.868	-0.069	93.931
78.800	630.161	-315.919	0.094	-3.970	-0.153	93.961
79.200	629.973	-320.205	-0.035	-4.224	-0.230	93.965
79.600	629.809	-324.506	-0.204	-4.619	-0.272	93.934
80.000	629.682	-328.822	-0.387	-5.090	-0.253	93.859
80.400	629.591	-333.151	-0.552	-5.523	-0.164	93.733
80.800	629.521	-337.493	-0.662	-5.780	-0.019	93.552
81.200	629.446	-341.846	-0.684	-5.722	0.153	93.321
81.600	629.332	-346.209	-0.592	-5.229	0.306	93.056
82.000	629.149	-350.582	-0.385	-4.257	0.397	92.778
82.400	628.881	-354.967	-0.085	-2.868	0.402	92.505
82.800	628.527	-359.366	0.262	-1.206	0.319	92.253
83.200	628.107	-363.779	0.591	0.551	0.172	92.031
83.600	627.651	-368.208	0.842	2.223	0.000	91.843
84.000	627.193	-372.652	0.963	3.644	-0.156	91.681
84.400	626.767	-377.110	0.931	4.675	-0.265	91.535
84.800	626.403	-381.580	0.751	5.219	-0.310	91.394
85.200	626.122	-386.060	0.453	5.240	-0.292	91.249
85.600	625.936	-390.548	0.092	4.769	-0.224	91.098
86.000	625.844	-395.043	-0.271	3.918	-0.131	90.946
86.400	625.832	-399.545	-0.576	2.841	-0.037	90.801
86.800	625.880	-404.055	-0.776	1.686	0.036	90.673
87.200	625.962	-408.571	-0.844	0.578	0.076	90.566
87.600	626.047	-413.095	-0.774	-0.372	0.085	90.481
88.000	626.105	-417.628	-0.577	-1.061	0.073	90.415
88.400	626.108	-422.168	-0.280	-1.394	0.054	90.367
88.800	626.030	-426.718	0.075	-1.315	0.038	90.337
89.200	625.862	-431.276	0.439	-0.830	0.031	90.326

89.600	625.610	-435.842	0.756	-0.028	0.029	90.333
90.000	625.295	-440.417	0.973	0.933	0.026	90.355
90.400	624.950	-445.001	1.052	1.863	0.016	90.385
90.800	624.616	-449.594	0.974	2.573	-0.006	90.414
91.200	624.329	-454.194	0.746	2.907	-0.036	90.431
91.600	624.122	-458.802	0.397	2.770	-0.069	90.426
92.000	624.017	-463.417	-0.023	2.159	-0.094	90.394
92.400	624.020	-468.038	-0.455	1.175	-0.102	90.336
92.800	624.124	-472.664	-0.840	0.005	-0.091	90.263
93.200	624.305	-477.293	-1.124	-1.151	-0.063	90.192
93.600	624.530	-481.926	-1.273	-2.123	-0.028	90.136
94.000	624.765	-486.562	-1.270	-2.801	0.004	90.100
94.400	624.979	-491.201	-1.121	-3.116	0.028	90.084
94.800	625.144	-495.843	-0.847	-3.018	0.043	90.081
95.200	625.238	-500.490	-0.482	-2.482	0.051	90.087
95.600	625.244	-505.142	-0.068	-1.535	0.053	90.098
96.000	625.157	-509.800	0.350	-0.266	0.052	90.116
96.400	624.982	-514.463	0.726	1.181	0.045	90.139
96.800	624.734	-519.131	1.019	2.636	0.033	90.166
97.200	624.439	-523.806	1.201	3.931	0.015	90.193
97.600	624.124	-528.486	1.258	4.914	-0.008	90.217
98.000	623.815	-533.171	1.194	5.469	-0.033	90.233
98.400	623.538	-537.860	1.025	5.516	-0.054	90.237
98.800	623.311	-542.553	0.780	5.029	-0.068	90.228
99.200	623.148	-547.248	0.489	4.046	-0.072	90.208
99.600	623.059	-551.945	0.185	2.669	-0.065	90.179
100.000	623.043	-556.645	-0.107	1.041	-0.048	90.149
100.400	623.098	-561.346	-0.364	-0.681	-0.027	90.121
100.800	623.212	-566.049	-0.570	-2.340	-0.005	90.098
101.200	623.366	-570.755	-0.709	-3.788	0.013	90.081
101.600	623.533	-575.463	-0.772	-4.882	0.026	90.070
102.000	623.687	-580.174	-0.750	-5.505	0.033	90.067
102.400	623.802	-584.887	-0.650	-5.586	0.033	90.075
102.800	623.866	-589.602	-0.492	-5.128	0.026	90.095
103.200	623.882	-594.319	-0.312	-4.234	0.014	90.126
103.600	623.867	-599.039	-0.152	-3.075	-0.001	90.160
104.000	623.845	-603.762	-0.047	-1.836	-0.015	90.186
104.400	623.837	-608.488	-0.016	-0.660	-0.024	90.194
104.800	623.855	-613.218	-0.051	0.376	-0.025	90.178
105.200	623.896	-617.952	-0.119	1.270	-0.016	90.139
105.600	623.942	-622.688	-0.175	2.070	-0.002	90.086
106.000	623.969	-627.426	-0.177	2.825	0.014	90.033
106.400	623.956	-632.164	-0.100	3.542	0.027	89.995
106.800	623.894	-636.902	0.048	4.165	0.032	89.979
107.200	623.789	-641.640	0.234	4.590	0.030	89.985
107.600	623.662	-646.380	0.408	4.704	0.023	90.004
108.000	623.537	-651.121	0.521	4.421	0.014	90.025
108.400	623.438	-655.866	0.546	3.719	0.006	90.038
108.800	623.376	-660.615	0.481	2.666	-0.002	90.034
109.200	623.353	-665.368	0.351	1.403	-0.007	90.015
109.600	623.356	-670.123	0.202	0.113	-0.012	89.989

110.000	623.367	-674.879	0.080	-1.037	-0.017	89.969
110.400	623.366	-679.635	0.019	-1.936	-0.024	89.965
110.800	623.341	-684.391	0.025	-2.544	-0.030	89.983
111.200	623.290	-689.145	0.083	-2.883	-0.034	90.020
111.600	623.222	-693.899	0.157	-3.012	-0.032	90.066
112.000	623.150	-698.653	0.204	-2.997	-0.023	90.111
112.400	623.090	-703.408	0.193	-2.897	-0.009	90.144
112.800	623.057	-708.165	0.107	-2.747	0.006	90.160
113.200	623.062	-712.925	-0.050	-2.563	0.017	90.158
113.600	623.113	-717.688	-0.252	-2.341	0.020	90.142
114.000	623.209	-722.452	-0.463	-2.072	0.014	90.116
114.400	623.345	-727.218	-0.643	-1.739	0.002	90.085
114.800	623.507	-731.985	-0.752	-1.321	-0.013	90.052
115.200	623.672	-736.752	-0.760	-0.782	-0.023	90.020
115.600	623.811	-741.518	-0.652	-0.085	-0.024	89.992
116.000	623.895	-746.283	-0.429	0.791	-0.015	89.972
116.400	623.900	-751.047	-0.118	1.817	0.004	89.964
116.800	623.819	-755.811	0.235	2.907	0.026	89.971
117.200	623.659	-760.575	0.570	3.932	0.044	89.992
117.600	623.442	-765.341	0.827	4.747	0.052	90.023
118.000	623.200	-770.109	0.960	5.216	0.045	90.055
118.400	622.965	-774.880	0.948	5.232	0.026	90.083
118.800	622.767	-779.654	0.795	4.735	-0.003	90.099
119.200	622.627	-784.431	0.532	3.749	-0.033	90.098
119.600	622.556	-789.209	0.207	2.378	-0.056	90.081
120.000	622.555	-793.988	-0.126	0.782	-0.067	90.052

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This report serves as a user manual for simulating ship motions in waves and in calm water using ShipMo3D Version 1.0. ShipMo3D is an object-oriented library with associated user applications for predicting ship motions in both the time domain and frequency domain. This report covers simulation in the time domain, and a companion report serves as a user manual for predicting ship motions in the frequency domain. Several ShipMo3D applications are used for obtaining a simulation in the time domain. SM3DPanelHull creates a panelled representation of the ship hull using input offsets. SM3DRadDif generates a database of radiation and diffraction coefficients that contribute to the efficiency of subsequent simulations. SM3DBuildShip creates a model of the ship, including required data for the hull geometry, radiation and diffraction properties, and appendage geometries. SM3DBuildSeaway creates a model of a seaway, which can consist of either regular waves or random waves, with capabilities for modelling both unidirectional and multidirectional seaways. SM3DFreeMo simulates motions of a ship using input data prepared by the user and produced by the previously mentioned ShipMo3D applications.

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